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# NUMERICAL ANALYSIS OF SUPERSONIC FLOW THROUGH CURVED CHANNELS

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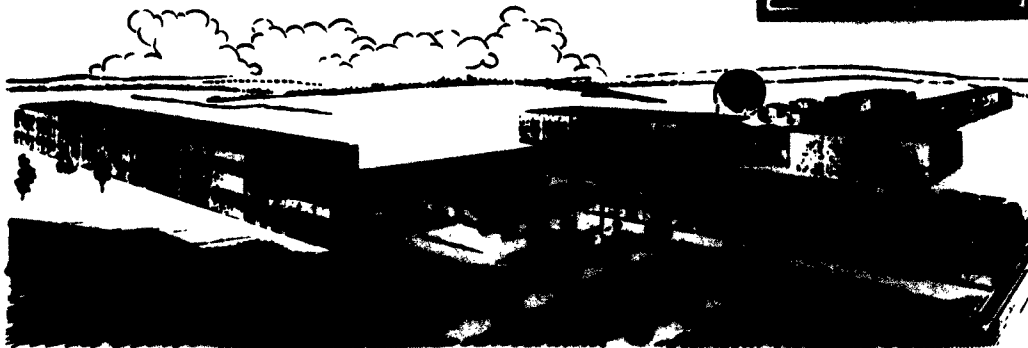
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ARL 63-117

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**JULY 1963**

**Contract AF 33(657)-8851  
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Task 7065-01**

**AEROSPACE RESEARCH LABORATORIES  
OFFICE OF AEROSPACE RESEARCH  
UNITED STATES AIR FORCE  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO**

#### FOREWORD

This final technical report was prepared by Northrop Norair, Hawthorne, California on Contract AF 33(657)-8851 for the Aeronautical Research Laboratories, Office of Aerospace Research, United States Air Force. The work reported herein was accomplished on Task 7065-01, "Fluid Dynamics Facilities Research" of Project 7065, "Aerospace Simulation Techniques Research" under the technical cognizance of Lt Arthur Wennerstrom of the Fluid Dynamics Facilities Laboratory of ARL. Report number NOR 63-59 has been assigned to this report for internal control.

# ABSTRACT

This report describes an IBM FORTRAN program for calculating supersonic flows through curved channels. Included in the program are: 1) a second order Belotserkovskii procedure for calculating the flow field around the forward part of blunt blades, 2) a general method of characteristics procedure for calculating supersonic flow fields, 3) automatic procedures for calculating interactions of shocks of opposite families, shock interactions with a wall and with a vortex sheet or slipstream, 4) a finite difference laminar boundary-layer procedure for calculating viscous region of the flow. Three sample calculations as well as the listing of the FORTRAN program are presented.

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**LIST OF SYMBOLS  
(BLUNT BODY SOLUTIONS)**

<b>SYMBOL</b>	<b>DESCRIPTION</b>
$x, y$	Cartesian coordinates
$r, \theta$	Polar coordinates
$M$	Mach number
$w, p, \rho$	Dimensionless speed, pressure, density
$w_x, w_y$	Velocity components (x, y directions)
$u, v$	Velocity components (r, $\theta$ directions)
$\varphi = p/\rho^\gamma$	Entropy function
$\psi$	Stream function
$\gamma$	Adiabatic index
$k$	$(\gamma-1)/2\gamma$
$\sigma$	Angle between tangent to shock wave and incident stream
$\epsilon(\theta)$	Distance between body and shock measured along radius vector
$t$	$\tau v$
$\tau$	$(1-w^2)^{\frac{1}{\gamma-1}}$
$s$ $g$	$\frac{\rho uv}{2kp + \rho v^2}$
$H$	$kp + \rho u^2$
$h$	$\tau u$

Other symbols are defined in the text. Velocities are made dimensionless in terms of the maximum velocity, pressure and density in terms of corresponding stagnation values.

## LIST OF SYMBOLS (Continued)

### INDEXES

$\infty$	Value in free stream
0	Value on body surface
1	Value behind shock
2	Value on half way line

**LIST OF SYMBOLS**  
**(BOUNDARY LAYER EQUATIONS)**

SYMBOL	DESCRIPTION
$(\bar{\phantom{x}}), (\phantom{x})'$	dimensional quantity
$(\phantom{x})_0$	reference quantity
$(\phantom{x})_{i,j,k}$	lattice quantity
a, b, c	lattice spacings
$C_p$	specific heat at constant pressure
$h_1, h_2, h_3$	metrical coefficients; $h_1 = \frac{\partial \bar{x}}{\partial \xi}$ , $h_2 = \frac{\partial \bar{y}}{\partial \eta}$ , $h_3 = \frac{\partial \bar{z}}{\partial \zeta}$ where $\bar{x}$ , $\bar{y}$ , and $\bar{z}$ curvilinear distance along $\xi$ , $\eta$ , and $\zeta$ respectively
i, j, k	lattice indices
$\ell$	total enthalpy
p	absolute static pressure
$\mathcal{R}$	universal gas constant
t	boundary-layer internal absolute temperature
u, v, w	boundary-layer internal velocity components in $\xi$ , $\eta$ , $\zeta$ directions; i.e., the velocity components within the boundary layer
x, y, z	curvilinear distances along body surfaces in $\xi$ , $\eta$ , $\zeta$ directions
A	flow parameter, defined in Eq 6
B	coefficients of the differential equations (7) defined in Eq 13
L	geometrical length
M	Mach number
$P_r$	Prandtl number, $P_r = \frac{\bar{\mu} \bar{c}_p}{\bar{k}}$
Q	resultant velocity

# LIST OF SYMBOLS (Continued)

SYMBOL	DESCRIPTION
R	Reynolds number
T	absolute temperature (external)
U, V, W	boundary-layer external velocity components in $\xi$ , $\eta$ , $\zeta$ directions; i.e., the velocity components appropriate to the inviscid flow field evaluated at the outer edge of the boundary layer
$\delta$	boundary-layer thickness
$\kappa$	thermal conductivity
$\lambda$	boundary-layer internal density
$\mu$	boundary-layer internal absolute viscosity
$(\mu)_{\zeta=0}$	boundary-layer external viscosity
$\xi, \eta, \zeta$	curvilinear coordinates
$\xi^*$	singularity factor
$\varphi$	shear coefficient
$\Lambda$	boundary-layer external density

**LIST OF SYMBOLS  
(APPENDICES)**

<b>SYMBOL</b>	<b>DESCRIPTION</b>
<b>A, B, C, D</b>	- Coefficients of a cubic ( $AX^3 + BX^2 + CX + D$ )
<b>M</b>	- Mach Number
<b>P</b>	- Local Static Pressure
<b>R</b>	- Local Total Pressure
<b>X, Y</b>	- Coordinates of a point
<b><math>\gamma</math></b>	- Ratio of Specific Heats
<b><math>\delta</math></b>	- Flow Deflection Angle
<b><math>\theta</math></b>	- Flow Direction
<b><math>\mu</math></b>	- Mach Angle
<b><math>\omega</math></b>	- Shock Angle

**SUBSCRIPTS**

<b>o</b>	- Zeroth Approximation
<b>i</b>	- Current (ith) Approximation
<b><math>\overline{2, 3}, \overline{1, 2}</math>, etc.</b>	- Average of Properties at the two points
<b>+</b>	- Incident Shock Properties
<b>-</b>	- Transmitted Shock Properties

## I INTRODUCTION

The behavior of supersonic flow through cascade depends strongly on the complex system of the shock wave and vortex sheet interactions which develop from the blade leading edges during the turning process. The flow system in a supersonic inlet channel must swallow the initial shocks generated by the leading edges of the blades. The bow shocks will eventually interact and a vortex sheet (or slipstream) or new shocks and/or expansion waves will be generated which will cause various combinations of shock wave interactions further downstream (Figure 2). To determine the true performances of a supersonic cascade, these interactions must be accurately calculated.

Near the two surfaces of the channel the flow is also complicated by the existence of the boundary layer. On the concave or compression side of the walls, the strong positive pressure gradient can cause boundary layer separation which greatly decreases the channel efficiency. Shock wave-boundary layer interaction occur when shocks impinge on the blade surfaces. The sudden pressure rise across the shocks can easily cause boundary layer separation or even boundary layer transition. Also, the fact that the boundary layer displaces the inviscid flow field gives rise to viscous-inviscid interaction effects.

Another problem arises from the fact that the velocity is discontinuous across a vortex sheet. In actual flows, this velocity discontinuity is modified by viscous mixing. The mixing problem, however, is beyond the scope of the present report.

This report describes a FORTRAN language computer program, developed for the IBM 7090, for calculating inviscid and viscous flow fields within two-dimensional supersonic curved channels. The channel surface leading edges can be either sharp or blunted. The complete channel flow field is divided into three regions; each of which is calculated by an independently developed numerical procedure. These procedures are chained together in the overall program to provide automatic calculation. These three regions are the blunt body, supersonic, and boundary layer flow fields. The blunt body flow field, located ahead of a blunt leading edge is computed by the second order Pelotserkovskii method (Reference 1), the supersonic flow field is computed by the method of characteristics, (References 4, 5 and 6), and the boundary layer or the viscous flow field is computed by a finite difference procedure (References 2 & 3). Singularities that can be treated by the program are: interactions of shocks of opposite family; vortex sheet; interactions of shocks with a vortex sheet; the wall of the boundary layer; and viscous-inviscid interaction effects which are directly related to the boundary displacement. It is assumed that the inviscid flow field is supersonic throughout, except in the blunt leading edge region.

Three sample calculations are presented. Mach 4 and Mach 6 cases were computed for a sharp leading-edge channel, and a Mach 4 case was computed for a blunt leading-edge channel.

## II CHANNEL AND FLOW MODELS

The flow channels as formed by a cascade are shown in Figure 1. The blades or the turning vanes being treated can have either sharp or blunt leading edges. Typical design values initially given for studies are the incident angle  $\alpha$ , turning angle  $\beta$ , and the incident Mach number  $M_\infty$ . In the numerical calculation, the channel and flow characteristics are defined on a cartesian coordinate system  $x$  and  $y$ , where  $x$  is parallel and  $y$  is perpendicular to the incident flow direction.

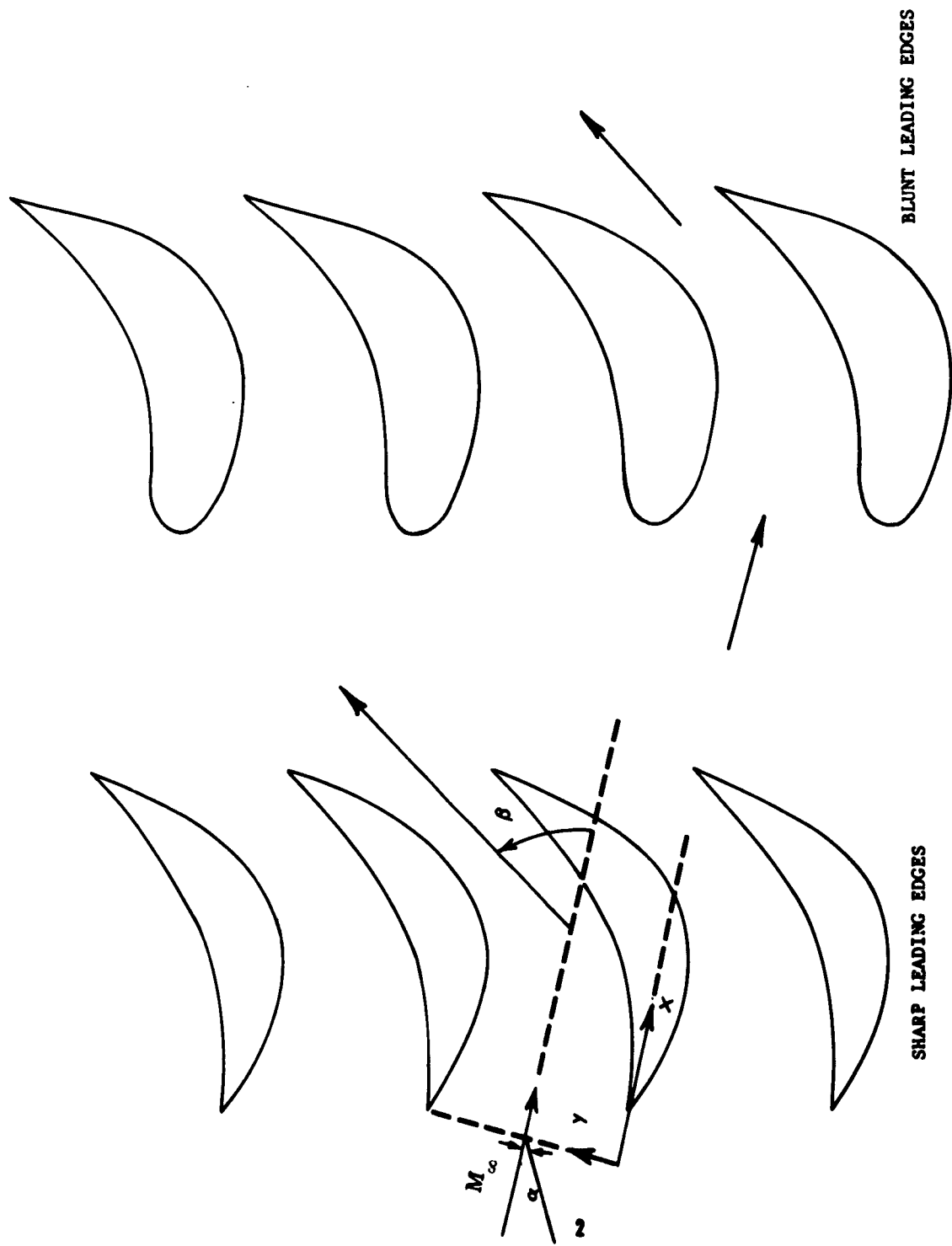


FIGURE 1 CHANNEL FLOW IN CASCADE

Figure 2 shows a schematic diagram of the channel flow model considered in the present computer program in which it is assumed that the inviscid flow field remains supersonic downstream of the leading edges. Two initial bow shocks will be generated by the two leading edges. For the cases with blunt leading edges, a blunt body procedure is required to calculate the initial portions of the bow shocks along with a special procedure to calculate the two starting supersonic characteristics. For sharp leading edges, the usual wedge flow solutions apply. The bow shocks will eventually intersect as they extend downstream. At the shock intersection point, a vortex sheet or slipstream will be created. When the shocks impinge on the blade surfaces, they will be deflected again into the flow field and interact with the vortex sheet. At the point of shock interaction with a vortex sheet, a new expansion (Prandtl-Meyer fan) or a compression (shock) wave will be created depending on the flow conditions.

When the inviscid flow solution has been determined, the boundary layers developed on the blade surfaces can be calculated. Shock wave-boundary layer interactions are treated by spreading the pressure jump (or velocity discontinuity) across the shock along the surface. The spreading distance is a function of the local boundary layer thicknesses. Viscous-inviscid interaction effects are treated by increasing the channel width locally by the boundary layer displacement distribution.

### III EQUATIONS AND NUMERICAL TECHNIQUE

Three basic numerical procedures are used in constructing the overall computer program. These procedures are: the Belotserkovskii method for calculating flows around the blunt leading edges, the method of characteristics for calculating supersonic flow fields, and a finite difference procedure for calculating boundary layers. These methods and their equations are described below. Since the basic theory of the method of characteristics has been extensively described in the literature (References 4, 5, and 6), the basic inviscid flow equations have not been included. The calculation procedures, however, are summarized in the appendices. Since the methods described here have been described previously in the literature, the symbols used in the equations are essentially those of the originals. Since no attempt has been made to generalize the nomenclature, a list of symbols is given for each of the methods.

#### A. BLUNT BODY SOLUTIONS

The flow about the blunted nose is determined by using the direct method developed by Belotserkovskii (Reference 1). This method is based on a general technique proposed by Dorodnitsyn (Reference 7) for solving a system of first order partial differential equations of mixed type which have two independent variables. The technique consists of reducing the partial differential equations to ordinary differential equations in one independent variable by specifying the variation of the unknowns with the other independent variable.

The ordinary differential equations which result are integrated numerically. Most of the boundary conditions are given at the beginning of the range of integration but these must be supplemented by conditions that the solutions of one or more of the equations shall pass smoothly from the elliptic (subsonic) to the hyperbolic (supersonic) region. The conditions of smooth transition, together with the other boundary conditions, determine solutions of all unknowns uniquely (Reference 8).

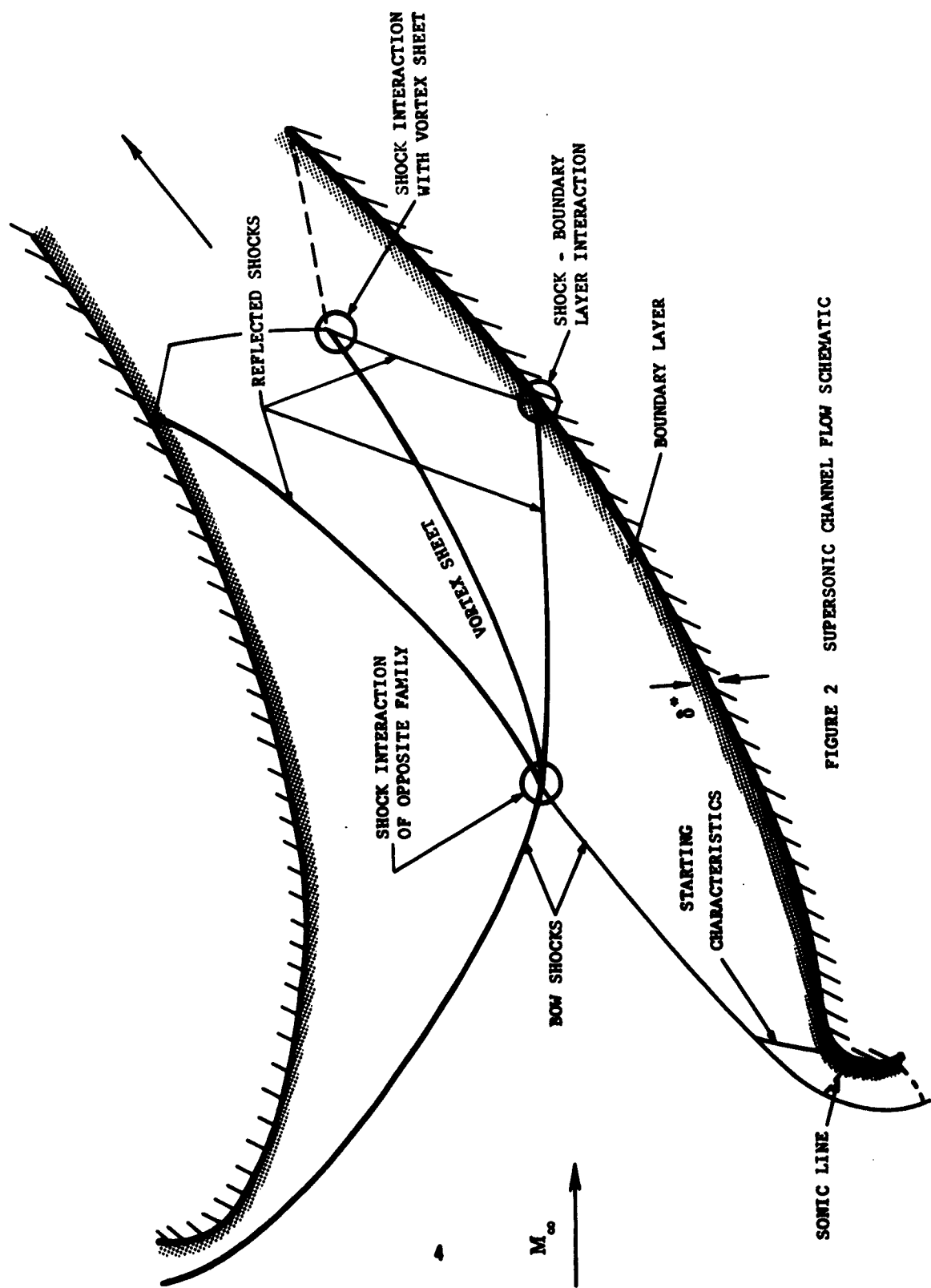


FIGURE 2 SUPERSONIC CHANNEL FLOW SCHEMATIC

Since the nose of the body is a circular cylinder, polar coordinates with the origin taken at the body geometric center are used. Figure 3 illustrates the geometry of the problem. Dimensionless variables are used whereby length is referred to cylinder radius, velocities are referred to the limiting speed, and pressure and density are referred to corresponding stagnation values in the free stream.

The fluid motion is governed by Bernoulli's equation, the equation of continuity, an equation obtained by combining the radial momentum equation with continuity, the condition of conservation of entropy along streamlines and the equation of state. The equations may be written:

Continuity equation

$$\frac{\partial}{\partial r} (rh) + \frac{\partial t}{\partial \theta} = 0 \quad (3a.1)$$

Modified momentum in the r-direction

$$\frac{\partial}{\partial r} (rH) + \frac{\partial s}{\partial \theta} - g = 0 \quad (3a.2)$$

In equations 3a.1 and 3a.2

$$H = kp + \rho u^2$$

$$s = \rho uv$$

$$g = kp + \rho v^2$$

$$h = \tau u$$

$$t = \tau v$$

Bernoulli's equation

$$p = \rho(1 - w^2) \quad (3a.3)$$

Conservation of entropy

$$\varphi = p/\rho^\gamma = \varphi(\psi) \quad (3a.4)$$

where  $\psi$  is the stream function defined below, and  $\varphi$  is a function of entropy.

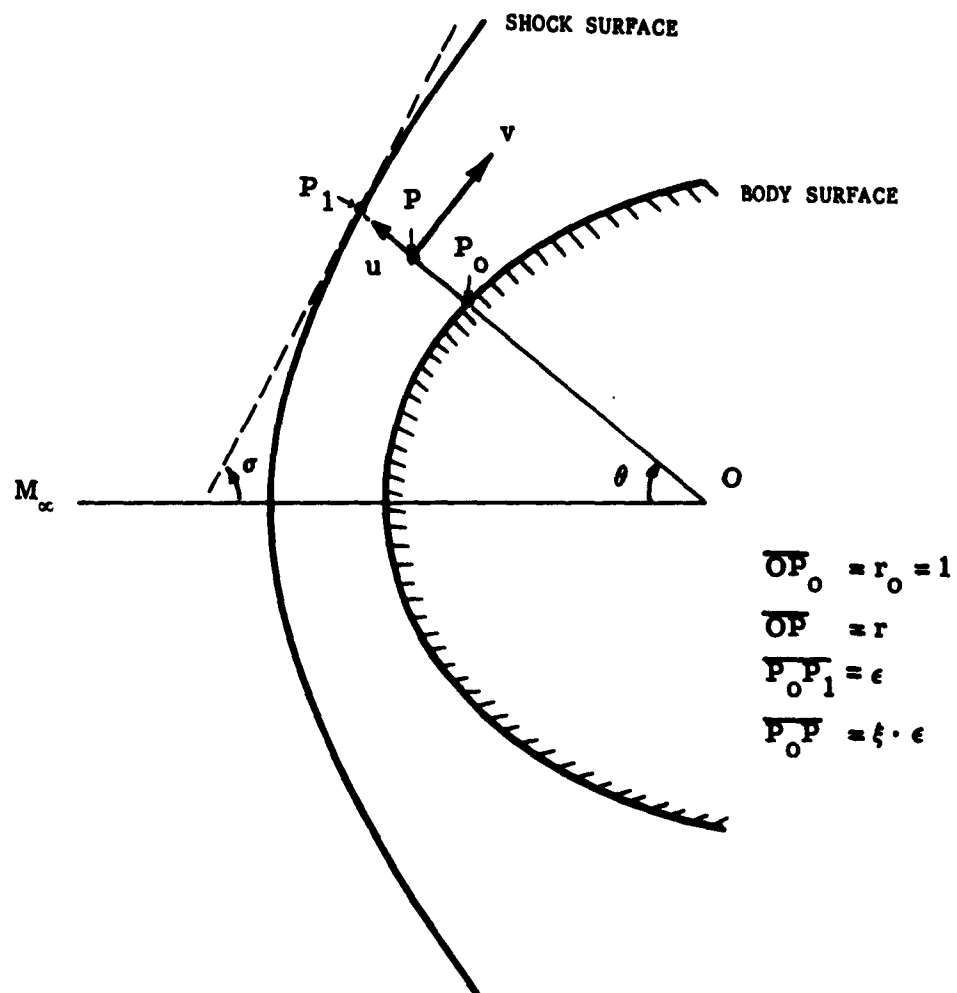


FIGURE 3 GEOMETRY OF BODY AND SHOCK

### Stream function

The equation of continuity leads to the stream function defined by:

$$\frac{\partial \psi}{\partial \theta} = -r \rho u \quad (3a.5)$$

$$\frac{\partial \psi}{\partial r} = \rho v$$

From Eqs (3a.3) and (3a.4):

$$p = \tau^\gamma \varphi^{-\frac{\gamma}{\gamma-1}} \quad (3a.6)$$

$$\rho = \tau \varphi^{-\frac{1}{\gamma-1}} \quad (3a.7)$$

where:  $\tau = (1 - w^2)^{\frac{1}{\gamma-1}}.$

From Eq (3a.5), on any line:

$$\frac{d\psi}{d\theta} = \rho (v \frac{dr}{d\theta} - ru). \quad (3a.8)$$

The speed of sound is determined from Bernoulli's equation:

$$c^2 = \gamma \frac{kp}{\rho} = \frac{\gamma-1}{2} (1 - w^2). \quad (3a.9)$$

The boundary conditions on the surface of the cylinder ( $r = r_0 = 1$ ) are:

$$u = \psi = 0$$

and:

$$\varphi = \frac{4\gamma}{\gamma^2-1} \left( \frac{\gamma-1}{\gamma+1} \right)^\gamma \frac{1}{w_\infty^{2\gamma}} \left[ \frac{w_\infty^2}{1-w_\infty^2} - \frac{(\gamma-1)^2}{4\gamma} \right]. \quad (3a.10)$$

The equation of the shock wave is:

$$r = r_1(\theta) = 1 + \epsilon(\theta) \quad (3a.11)$$

where  $\epsilon(\theta)$  is the distance from the body surface to the shock wave along a line  $\theta = \text{constant}$ .

The conservation conditions across the shock wave lead to the following relations. The velocity components behind the shock wave parallel and normal to the free stream velocity vector are:

$$\begin{aligned} w_x &= w_\infty \left[ 1 - \frac{2}{\gamma+1} \sin^2 \sigma \left( 1 - \frac{1}{M_\infty^2 \sin^2 \sigma} \right) \right] \\ w_y &= w_\infty \sin 2\sigma \left( 1 - \frac{1}{M_\infty^2 \sin^2 \sigma} \right) \frac{1}{\gamma+1}. \end{aligned} \quad (3a.12)$$

The radial and transverse velocity components are given by:

$$\begin{aligned} u_1 &= w_y \sin \theta - w_x \cos \theta \\ v_1 &= w_x \sin \theta + w_y \cos \theta. \end{aligned} \quad (3a.13)$$

The pressure and density are given by:

$$p_1 = \frac{4\gamma}{\gamma^2 - 1} (1 - w_\infty^2)^{\frac{\gamma}{\gamma-1}} \left[ \frac{w_\infty^2 \sin^2 \sigma}{1 - w_\infty^2} - \frac{(\gamma-1)^2}{4\gamma} \right] \quad (3a.14)$$

$$\rho_1 = \frac{\gamma+1}{\gamma-1} (1 - w_\infty^2)^{\frac{1}{\gamma-1}} \frac{w_\infty^2}{1 + (1 - w_\infty^2) \cot^2 \sigma}. \quad (3a.15)$$

Since  $\phi = p/\rho^\gamma$ , one obtains:

$$\phi = \frac{4\gamma}{\gamma^2 - 1} \left( \frac{\gamma-1}{\gamma+1} \right)^\gamma \left[ \omega - \frac{(\gamma-1)^2}{4\gamma} \right] \left( 1 + \frac{1}{\omega} \right)^\gamma \quad (3a.16)$$

where:

$$\omega = \frac{w_\infty^2 \sin^2 \sigma}{1 - w_\infty^2}.$$

The value of the stream function  $\psi$  is determined from the condition of continuity across the shock wave. Thus:

$$\psi = \psi_\infty = w_\infty (1 - w_\infty^2)^{\frac{1}{\gamma-1}} (1 + \epsilon) \sin \theta. \quad (3a.17)$$

From the geometric relationship on the shock wave,  $\frac{dy}{dx} = \tan \sigma$ , one obtains the equation for  $\epsilon(\theta)$ .

$$\frac{d\epsilon}{d\theta} = -(1 + \epsilon) \cot(\sigma + \theta) \quad (3a.18)$$

The approximating system of equations is obtained as follows. Introduce the new independent variable:

$$\xi = \frac{r-1}{\epsilon(\theta)} \quad (3a.19)$$

After changing independent variables from  $(r, \theta)$  to  $(\xi, \theta)$  and integrating Eqs (3a.1) and (3a.2) along a line  $\theta = \text{constant}$  from  $\xi = 0$  to  $\xi = \xi_1$ , one gets:

$$r_1 h_1 - r_1' t_1 + \frac{\partial}{\partial \theta} \int_0^{\xi_1} \epsilon t d\xi = 0 \quad (3a.20)$$

$$r_1 H_1 - H_0 - r_1' s_1 + \frac{\partial}{\partial \theta} \int_0^{\xi_1} \epsilon s d\xi = \int_0^{\xi_1} \epsilon g d\xi. \quad (3a.21)$$

To obtain the approximating system of ordinary differential equations, the layer between the body and shock wave is divided into  $N$  equally spaced strips and the integrals in Eqs (3a.20) and (3a.21) are evaluated on successive boundaries of these strips. The unknown functions in the integrals are approximated by interpolation polynomials of degree  $N$  in  $\xi$  taking the interpolation points to be the strip boundaries:

$$f(\xi, \theta) = \sum_{k=0}^N a_k(\theta) \xi^k, \quad (3a.22)$$

where the coefficients  $a_k(\theta)$  are linear functions of the values of  $f$  on the strip boundaries.

Writing Eqs (3a.20) and (3a.21) along each of the  $N-1$  intermediate lines,

$\xi_1 = \frac{N-1+1}{N}$  ( $\psi$  and  $\varphi$  on the shock wave and on the body are determined from the boundary conditions), and taking Eq (3a.18) into account, one obtains an approximating system of  $4N-1$  equations for the unknowns:

$$\epsilon, \sigma, v_0, u_1, v_1, \psi_1, \varphi_1 \quad (i = 2, 3, \dots, N).$$

In Reference 1 it was shown that the convergence of this method with increasing  $N$  is extremely rapid, so that  $N = 2$  is sufficient for most purposes. This is termed the "second approximation" and is the one that is used here.

In the second approximation, the system of equations is:

$$\frac{d\epsilon}{d\theta} = -(1 + \epsilon) \cot(\sigma + \theta)$$

$$\frac{d\sigma}{d\theta} = F_2 \quad (3a.23)$$

$$\frac{dv_0}{d\theta} = \frac{E_0}{D_0} \quad (3a.24)$$

where:

$$E_0 = \frac{2 c_0^2}{(\gamma+1) \tau_0} t_0', D_0 = \frac{\gamma-1}{\gamma+1} - v_0^2$$

$$\frac{d\psi_2}{d\theta} = \rho_2 \left[ \frac{1}{2} v_2 \epsilon' - \left( 1 + \frac{\epsilon}{2} \right) u_2 \right] \quad (3a.25)$$

$$\frac{du_2}{d\theta} = \frac{1}{t_2 \varphi_2 - \frac{1}{\gamma-1}} \left[ S_2' - u_2 \varphi_2^{-\frac{1}{\gamma-1}} t_2' + \frac{S_2}{\gamma-1} \frac{d \ln \varphi_2}{d \psi_2} \frac{d \psi_2}{d \theta} \right] \quad (3a.26)$$

$$\frac{dv_2}{d\theta} = \frac{E_2}{D_2} \quad (3a.27)$$

where:

$$E_2 = \frac{2}{\gamma+1} \frac{c_2^2}{\tau_2} \left( t_2' + \frac{t_2 u_2}{c_2^2} u_2' \right)$$

$$D_2 = \frac{\gamma-1}{\gamma+1} - w_2^2 + \frac{2}{\gamma+1} u_2^2$$

$$\varphi_2 = \varphi(\psi_2) \quad (3a.28)$$

Quantities appearing in Eqs (3a.18), (3a.23-3a.28) are given by:

$$F_2 = \left[ S_1' - \rho_1 (v_1^2 - u_1^2) \right] / D_1 \quad (3a.29)$$

$$S_1' = \frac{\epsilon'}{\epsilon} (3 S_1 - 4 S_2) - \frac{4}{\epsilon} \left[ H_0 + (1 + \epsilon) H_1 - (2 + \epsilon) H_2 \right] + g_1 - g_0 \quad (3a.30)$$

$$S_2' = \frac{1}{2\epsilon} \left[ \epsilon' S_1 + 5 H_0 - 2(2 + \epsilon) H_2 - (1 + \epsilon) H_1 \right] + g_2 + \frac{1}{2} g_0 \quad (3a.31)$$

$$t_0' = t_1' + \frac{\epsilon'}{\epsilon} (4 t_2 - t_0 - 3 t_1) + \frac{4}{\epsilon} \left[ (1 + \epsilon) h_1 - (2 + \epsilon) h_2 \right] \quad (3a.32)$$

$$t_2' = -\frac{t_1'}{2} + 2 \frac{\epsilon'}{\epsilon} (t_1 - t_2) + \left( \frac{2 + \epsilon}{\epsilon} \right) h_2 - \frac{5}{2} \frac{1 + \epsilon}{\epsilon} h_1 \quad (3a.33)$$

$$t_1' = G_1 \frac{d\sigma}{d\theta} - h_1 \quad (3a.34)$$

and:

$$\frac{d \ln \varphi_2}{d \psi_2} = \left[ \frac{d \ln \varphi_1}{d \sigma} \cdot \frac{d \sigma}{d \theta} \right] \bigg/ \frac{d \psi_1}{d \theta} \quad \psi_2 = \psi_1 \quad (3a.35)$$

where:

$$\frac{d \ln \varphi_1}{d \sigma} = 2 \cot \sigma \frac{(\omega - \frac{\gamma-1}{2})^2}{(1 + \omega) \left[ \omega - \frac{(\gamma-1)^2}{4\gamma} \right]} \quad (3a.36)$$

$$\frac{d \psi_1}{d \theta} = w_\infty (1 - w_\infty^2)^{\frac{1}{\gamma-1}} \left[ \epsilon' \sin \theta + (1 + \epsilon) \cos \theta \right] \quad (3a.37)$$

and:

$$D_1 = \frac{4\gamma}{\gamma^2 - 1} w_\infty^2 (1 - w_\infty^2)^{\frac{1}{\gamma+1}} \frac{u_1 v_1 \sin 2\sigma}{1 - w_1^2} \quad (3a.38)$$

$$+ \rho_1 \left\{ v_1 m_1 - u_1 \left[ n_1 + \frac{2v_1}{1 - w_1^2} (v_1 n_1 - u_1 m_1) \right] \right\} \quad (3a.39)$$

$$G_1 = \tau_1 \left[ \frac{v_1}{c_1^2} (v_1 n_1 - u_1 m_1) - n_1 \right]$$

$$m_1 = \frac{d w_y}{d \sigma} \sin \theta - \frac{d w_x}{d \sigma} \cos \theta \quad (3a.40)$$

$$n_1 = -\frac{dw_x}{d\sigma} \sin \theta - \frac{dw_y}{d\sigma} \cos \theta \quad (3a.41)$$

$$\frac{dw_x}{d\sigma} = -\frac{2w_\infty}{\gamma+1} \sin 2\sigma \quad (3a.42)$$

$$\frac{dw_y}{d\sigma} = \frac{2w_\infty}{\gamma+1} \left( \cos 2\sigma + \frac{1}{M_\infty^2 \sin^2 \sigma} \right) \quad (3a.43)$$

The integration of the above system is carried out numerically and begins at the axis of symmetry  $\theta = 0$ , where  $\sigma = \frac{\pi}{2}$ ,  $v_0 = v_2 = \psi_2 = 0$  while the values  $\epsilon(0)$  and  $u_2(0)$  are unknown.

Examination of the equations for  $v_0$  and  $v_2$  reveals that singular points exist where:

$$v_0^2 = \frac{\gamma-1}{\gamma+1} \quad \text{and} \quad w_2^2 = \frac{\gamma-1}{\gamma+1} + \frac{2u_2^2}{\gamma+1};$$

that is, where the transverse velocity components on the body and on the mid-way line become sonic. In order for a continuous solution to exist, one requires that:

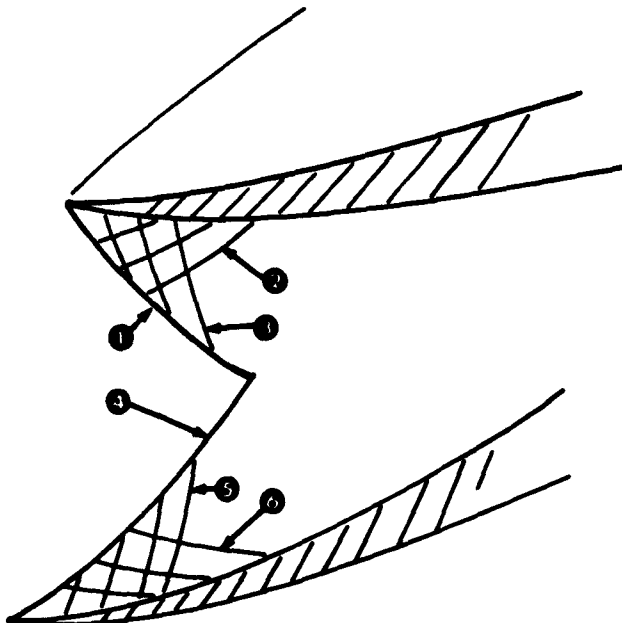
$$\left. \begin{aligned} E_0 &= 0 \quad \text{when} \quad D_0 = 0 \\ E_2 &= 0 \quad \text{when} \quad D_2 = 0. \end{aligned} \right\} \quad (3a.44)$$

Otherwise  $v'_0$  and  $v'_2$  become infinite at the singular points and the solution is physically meaningless. Thus the two conditions of smoothness determine the proper values of  $\epsilon(0)$  and  $u_2(0)$ . Since one is dealing with a two point boundary value problem, iteration must be used to determine the correct values of  $\epsilon(0)$  and  $u_2(0)$ . Once this is done the numerical integration is continued a short distance into the supersonic region where an initial value line is generated to start the characteristic procedure.

The initial value line is a set of 20 equally spaced points along a line  $\theta =$  constant between body and shock wave. Since only the flow quantities on the body, mid-way line and shock are known from the solution, additional quantities in between are obtained by fitting quadratics to  $u$ ,  $v$  and  $\phi$ . All other flow properties may be determined from these three.

## B. METHOD OF CHARACTERISTICS

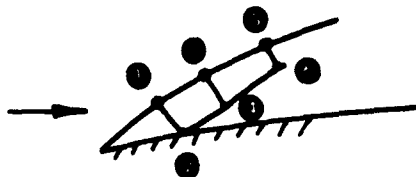
The supersonic inviscid flow field is solved by the method of characteristics, with the calculation proceeding along left-running characteristics. Special treatment is required for singularities in the form of shocks and contact surfaces. In the following discussion the characteristics and shocks will be labeled as follows:



- ① Left running shock of the second family
- ② Right running characteristics of the second family
- ③ Left running characteristic of the second family
- ④ Left running shock of the first family
- ⑤ Left running characteristic of the first family
- ⑥ Right running characteristic of the first family

### Starting Region For Pointed Blades

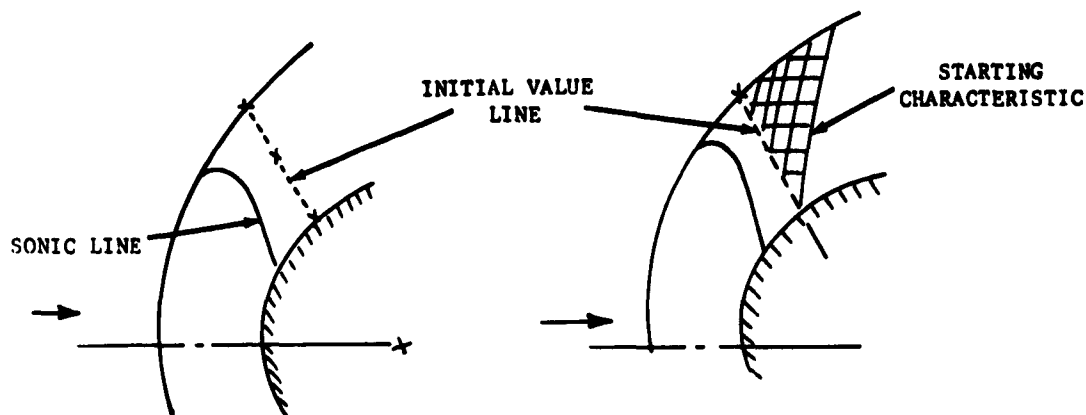
Initial values for the method of characteristics on pointed blades are obtained from the solution for the flow on a two dimensional wedge. The shock angle at the leading edge of the blade is determined by incident flow and leading edge angle. The procedure then enters a body point procedure and erects a right running characteristic from the shock to the body. Using this body point a new shock point is calculated which is used to calculate a new field point. The order in which the points are calculated is shown in the sketch below:



Left running characteristics are built up until they intersect the shock wave. In this way the inviscid flow field behind the bow shocks can be calculated up to the point where the shock waves interact.

#### Starting Region For Blunt Blades

The determination of the subsonic flow region of blunt blades has been described in the previous section. The Belotserkovskii solution can be used for a short distance into the supersonic flow region to provide an initial value line for the method of characteristics solution. The blunt body solution provides values at three points: at the shock, midway between the shock and body, and at the body. Twenty points are then generated on a straight line running from the shock to the body using quadratic interpolation.

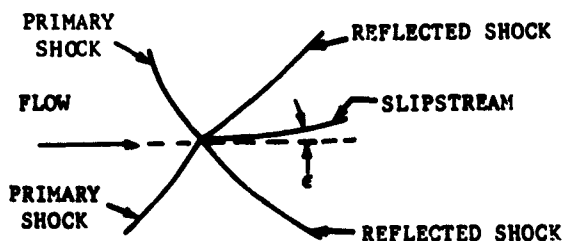


The initial value line is chosen such that the minimum Mach number of the three points from the Belotserkovskii solution is 1.1. The characteristics network is then built up until a complete left running characteristic is formed. After this the calculation proceeds as before until a shock interaction is reached.

#### Shock Interactions

##### a. Interactions Of Shocks Of Opposite Families

When two shocks of opposite family interact, two reflected shocks and a slipstream are produced:



The solution for the two reflected shocks must be iterated to determine a common flow deflection angle  $\epsilon$  behind each shock.

A good first approximation for this turning angle is the difference of the two flow turning angles across the primary shocks. The angle  $\epsilon$  is altered in the iteration process until the pressures match across the two reflected shocks. A similar procedure is used to calculate each point along the slipstream.

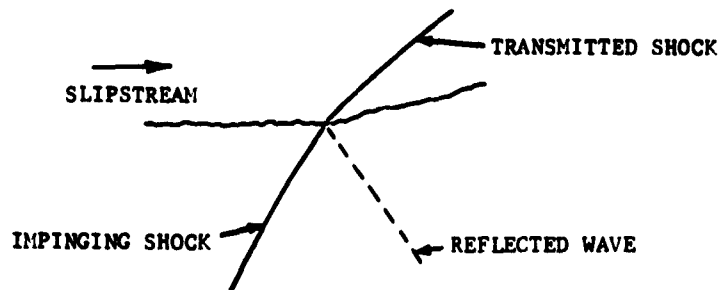
Conditions to be satisfied across the slipstream are that the pressure and flow direction match across it. Discontinuities exist, however, in temperature, velocity and stagnation pressure.

#### b. Shock Interactions With The Wall

The problem of calculating the interaction of a shock with a surface resembles that of calculating the interaction of two shocks of opposite families in that the surface corresponds to the slipstream. In the case of the interaction with a surface, however, the stream direction after the reflection is determined by the wall. The reflected shock is such that it matches the flow previously calculated downstream of the impinging shock with the flow calculated along left running characteristics after the reflected shock.

#### c. Shock Interaction With A Slipstream

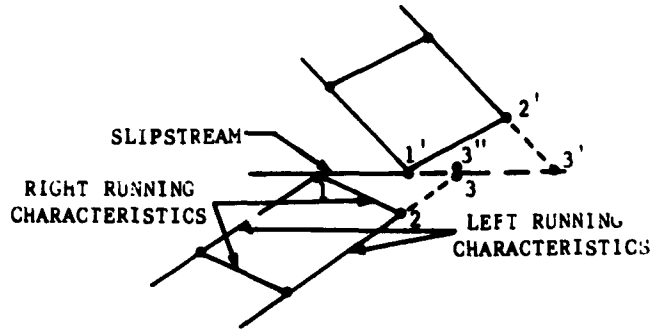
A shock interacting with a slipstream will produce a transmitted shock and a reflected wave, either expansion or compression:



As in the case of the interaction of shocks of opposite families, an initial slipstream direction is chosen which determines the angle (and strength) of the transmitted shock. The first approximation to the slipstream direction is taken as the flow direction after the impinging shock. The pressure matching condition is then imposed, and the flow direction is altered until this condition is satisfied. The flow direction immediately after the interaction point determines whether the reflected wave is an expansion or a compression.

### Slipstream Calculation

The flow direction and the static pressure must be the same across a slipstream. To calculate points along a slipstream, the flow direction must be iterated by applying the compatibility equations along the left running characteristics from both sides.



### C. BOUNDARY LAYER SOLUTIONS

Laminar boundary-layer solutions are obtained by a numerical method described in References (2 & 3). In this method, an explicit finite-difference technique is utilized to solve the exact boundary-layer equations for steady compressible flows. It is applicable to any smooth surface with arbitrary boundary conditions (pressure and temperature distributions, etc.).

Since the procedure used in this program was originally a general three-dimensional program, the equations described here are the original boundary layer equations in three dimensions. The equations in general curvilinear coordinates  $\xi, \eta, \zeta$  are:

$$\begin{aligned} \frac{\bar{u}}{\bar{h}_1} \frac{\partial \bar{u}}{\partial \xi} + \frac{\bar{v}}{\bar{h}_2} \frac{\partial \bar{u}}{\partial \eta} + \frac{\bar{w}}{\bar{h}_3} \frac{\partial \bar{u}}{\partial \zeta} + \frac{\bar{u}\bar{v}}{\bar{h}_1\bar{h}_2} \frac{\partial \bar{h}_1}{\partial \eta} - \frac{\bar{v}^2}{\bar{h}_1\bar{h}_2} \frac{\partial \bar{h}_2}{\partial \xi} = - \frac{1}{\lambda \bar{h}_1} \frac{\partial \bar{p}}{\partial \xi} \\ + \frac{1}{\lambda \bar{h}_3} \frac{\partial}{\partial \zeta} \left( \frac{\bar{\mu}}{\bar{h}_3} \frac{\partial \bar{u}}{\partial \zeta} \right) \end{aligned} \quad (1a)$$

$$\begin{aligned} \frac{\bar{u}}{\bar{h}_1} \frac{\partial \bar{v}}{\partial \xi} + \frac{\bar{v}}{\bar{h}_2} \frac{\partial \bar{v}}{\partial \eta} + \frac{\bar{w}}{\bar{h}_3} \frac{\partial \bar{v}}{\partial \zeta} - \frac{\bar{u}^2}{\bar{h}_1\bar{h}_2} \frac{\partial \bar{h}_1}{\partial \eta} + \frac{\bar{u}\bar{v}}{\bar{h}_1\bar{h}_2} \frac{\partial \bar{h}_2}{\partial \xi} = - \frac{1}{\lambda \bar{h}_2} \frac{\partial \bar{p}}{\partial \eta} \\ + \frac{1}{\lambda \bar{h}_3} \frac{\partial}{\partial \zeta} \left( \frac{\bar{\mu}}{\bar{h}_3} \frac{\partial \bar{v}}{\partial \zeta} \right) \end{aligned} \quad (1b)$$

$$\frac{\bar{u}}{h_1} \frac{\partial \bar{l}}{\partial \xi} + \frac{\bar{v}}{h_2} \frac{\partial \bar{l}}{\partial \eta} + \frac{\bar{w}}{h_3} \frac{\partial \bar{l}}{\partial \zeta} = \frac{1}{\bar{\lambda} h_3} \frac{\partial}{\partial \zeta} \left[ \frac{\bar{\mu}}{h_3} \left( \bar{u} \frac{\partial \bar{u}}{\partial \zeta} + \bar{v} \frac{\partial \bar{v}}{\partial \zeta} \right) + \frac{\bar{\kappa}}{h_3} \frac{\partial \bar{t}}{\partial \zeta} \right] \quad (1c)$$

$$\frac{\partial}{\partial \xi} (\bar{h}_2 \bar{h}_3 \bar{\lambda} \bar{u}) + \frac{\partial}{\partial \eta} (\bar{h}_1 \bar{h}_3 \bar{\lambda} \bar{v}) + \frac{\partial}{\partial \zeta} (\bar{h}_1 \bar{h}_2 \bar{\lambda} \bar{w}) = 0 \quad (1d)$$

where  $\xi$  and  $\eta$  represent a two-dimensional orthogonal curvilinear dimensionless coordinate system which is defined appropriately for the given body surface, and  $\zeta$  is orthogonal to  $\xi$  and  $\eta$  and corresponds to the vertical distance.  $h_1$ ,  $h_2$  and  $h_3$  are the metrical coefficients in the  $\xi$ ,  $\eta$  and  $\zeta$  directions respectively. For two dimensional flows, all properties, of course, are independent of the  $\eta$  coordinate.

The total enthalpy  $\bar{l}$  in Eq (1c) can be eliminated by making use of the relation:

$$\bar{l} = \frac{\bar{u}^2 + \bar{v}^2}{2} + \int \bar{c}_p dt \quad (2)$$

Substituting this expression into (1c) and combining it with Eq (1a), the energy equation becomes

$$\begin{aligned} \frac{\bar{u}}{h_1} \frac{\partial \bar{t}}{\partial \xi} + \frac{\bar{v}}{h_2} \frac{\partial \bar{t}}{\partial \eta} + \frac{\bar{w}}{h_3} \frac{\partial \bar{t}}{\partial \zeta} &= \frac{1}{\bar{c}_p \bar{\lambda}} \left( \frac{\bar{u}}{h_1} \frac{\partial \bar{p}}{\partial \xi} + \frac{\bar{v}}{h_2} \frac{\partial \bar{p}}{\partial \eta} \right) + \frac{\bar{\mu}}{\bar{c}_p \bar{\lambda} h_3^2} \left[ \left( \frac{\partial \bar{u}}{\partial \zeta} \right)^2 \right. \\ &\left. + \left( \frac{\partial \bar{v}}{\partial \zeta} \right)^2 \right] + \frac{1}{\bar{c}_p \bar{\lambda} h_3} \frac{\partial}{\partial \zeta} \left( \frac{\bar{\kappa}}{h_3} \frac{\partial \bar{t}}{\partial \zeta} \right) \end{aligned} \quad (1e)$$

The coordinate  $\zeta$  is defined as:

$$\zeta = \left( 1 - \frac{\bar{u}}{U} \right)^{1/2} \quad (3)$$

where  $\bar{u}$  and  $U$  are the dimensional internal and external longitudinal velocity components respectively. Therefore,  $\zeta$  varies, 0 to 1, from the outer edge of the boundary layer to the surface of the body.

A shear coefficient  $\bar{\varphi}$  is introduced, defined as:

$$\bar{\varphi} = \frac{\bar{\mu}}{2\zeta} \frac{\partial}{\partial \zeta} \left( \frac{\bar{u}}{U} \right) = - \frac{\bar{\mu}}{h_3} \quad (4)$$

The equation of state:

$$\bar{p} = \bar{\lambda} \bar{R} \bar{t} \quad (5)$$

is introduced to eliminate the density  $\bar{\lambda}$ , and the definition of  $\zeta$  removes explicit dependence on  $\bar{u}$ . As a result, the system of Eqs (1) is reduced to a system of four equations in the four unknowns  $v$ ,  $t$ ,  $\varphi$  and  $w$ .

$$A_5 (1 - \zeta^2)^2 + A_6 (1 - \zeta^2) v + A_3 \frac{\zeta \varphi w}{\mu} - A_7 v^2 = -A_8 t - A_4 \frac{\varphi}{\mu} \frac{\partial(\zeta \varphi)}{\partial \zeta} \quad (6a)$$

$$A_1 (1 - \zeta^2) \frac{\partial v}{\partial \xi} + A_2 v \frac{\partial v}{\partial \eta} - A_3 \frac{\varphi w}{\mu} \frac{\partial v}{\partial \zeta} - A_9 (1 - \zeta^2)^2 + A_{10} (1 - \zeta^2) v + A_{11} v^2 = -A_{12} t + A_4 \frac{\varphi}{\mu} \frac{\partial}{\partial \zeta} \left( \varphi \frac{\partial v}{\partial \zeta} \right) \quad (6b)$$

$$A_1 (1 - \zeta^2) \frac{\partial t}{\partial \xi} + A_2 v \frac{\partial t}{\partial \eta} - A_3 \frac{\varphi w}{\mu} \frac{\partial t}{\partial \zeta} = A_{13} (1 - \zeta^2) \frac{t}{c_p} + A_{14} \frac{vt}{c_p} + \left[ A_{15} \zeta^2 + A_{16} \left( \frac{\partial v}{\partial \zeta} \right)^2 \right] \frac{\varphi^2}{c_p \mu} + A_4 \frac{\varphi}{c_p \mu} \frac{\partial}{\partial \zeta} \left( \varphi \frac{\partial t}{\partial \zeta} \right) \quad (6c)$$

$$A_1 (1 - \zeta^2) \frac{\partial}{\partial \xi} \left( \frac{\mu}{\varphi} \right) + A_2 \frac{\partial}{\partial \eta} \left( \frac{\mu v}{\varphi} \right) - A_3 \frac{\partial w}{\partial \zeta} + (4A_5 + A_{17}) (1 - \zeta^2) \frac{\mu}{\varphi} + (2A_6 + A_{18}) \frac{\mu v}{\varphi} = 0 \quad (6d)$$

where

$$\begin{aligned} A_1 &= \xi^* & A_2 &= \frac{h_1}{h_2} \frac{\xi^*}{U} & A_3 &= \frac{h_1}{\xi^*} \\ A_4 &= \frac{h_1}{\xi^* (\mu)_{\zeta=0}} & A_5 &= \frac{\xi^*}{2} \frac{\partial \ln(UQ)}{\partial \xi} & A_6 &= \frac{\xi^* h_1}{2h_2 U} \frac{\partial \ln}{\partial \eta} (h_1 U Q) \\ A_7 &= \frac{\xi^*}{2h_2 U^2} \frac{\partial h_2}{\partial \xi} & A_8 &= \frac{\xi^*}{2U^2 Q^2 p} \frac{\partial p}{\partial \xi} & A_9 &= \frac{\xi^* U}{h_2} \frac{\partial h_1}{\partial \eta} \\ A_{10} &= \xi^* \frac{\partial \ln(h_2 Q)}{\partial \xi} & A_{11} &= \frac{\xi^* h_1}{h_2 U Q} \frac{\partial Q}{\partial \eta} & A_{12} &= \frac{\xi^* h_1}{h_2 U Q^2 p} \frac{\partial p}{\partial \eta} \\ A_{13} &= \frac{\xi^*}{p} \frac{\partial p}{\partial \xi} & A_{14} &= \frac{\xi^* h_1}{h_2 U p} \frac{\partial p}{\partial \eta} & A_{15} &= \frac{4h_1 U^2 Q^2}{\xi^* (\mu)_{\zeta=0}} \end{aligned}$$

$$A_{16} = \frac{h_1 Q^2}{\xi^* (\mu)} \Big|_{\xi=0}$$

$$A_{17} = \xi^* \frac{\partial}{\partial \xi} \ln \left( \frac{\xi^* h_2 p}{R^{1/2} U Q T} \right)$$

$$A_{18} = \frac{\xi^* h_1}{h_2 U} \frac{\partial}{\partial \eta} \ln \left( \frac{\xi^* p}{R^{1/2} U T} \right)$$

Here,  $A_1 \dots A_{18}$  are the boundary quantities that must be specified for the boundary layer integration. They are completely determined by the external inviscid flow conditions and the body surface geometry. They are evaluated in terms of the inviscid flow velocity vector distribution and the metrical coefficients in the  $\xi$  and  $\eta$  coordinates. Thus they are independent of the  $\xi$  coordinates.

The dimensional physical quantities in Eqs (1) are replaced by their dimensionless equivalents which are defined as:

$$x = \frac{\bar{x}}{\bar{L}_0}$$

$$y = \frac{\bar{y}}{\bar{L}_0}$$

$$z = \frac{R^{1/2}}{\xi^* \bar{L}_0} \int_0^{\bar{z}} \frac{\bar{\lambda}}{\bar{\Lambda}} d\bar{z}$$

$$h_1 = \frac{\bar{h}_1}{\bar{L}_0}$$

$$h_2 = \frac{\bar{h}_2}{\bar{L}_0}$$

$$h_3 = \frac{\bar{h}_3}{\bar{L}_0} \left( \frac{R^{1/2}}{\xi^*} \right) \left( \frac{\bar{\lambda}}{\bar{\Lambda}} \right)$$

$$u = \frac{\bar{u}}{\bar{Q}}$$

$$v = \frac{\bar{v}}{\bar{Q}}$$

$$w = \frac{\bar{w}}{\bar{U}} \left( \frac{\bar{\lambda}}{\bar{\Lambda}} \right) R^{1/2} \xi^*$$

$$t = \frac{\bar{x} \bar{t}}{\bar{Q}_0}$$

$$p = \frac{\bar{p}}{\bar{\Lambda}_0 \bar{Q}_0^2}$$

$$Q = \frac{\bar{Q}}{\bar{Q}_0}$$

$$\mu = \frac{\bar{\mu}}{t \bar{\mu}_0}$$

$$k = \frac{\bar{k}}{\bar{x} \bar{\mu}}$$

$$c_p = \frac{\bar{c}_p}{\bar{x}}$$

$$\psi = \frac{\mu}{2\xi} \frac{\partial}{\partial z} \left( \frac{u}{U} \right) = - \frac{\mu}{h_3}$$

$$U = \frac{\bar{U}}{\bar{Q}}$$

Subscript "o" denotes reference quantities. Upper case letters denote boundary layer external quantities.

$\bar{L}_0$  is an arbitrary reference length;  $R$  is the local Reynolds number defined as  $\bar{U} \bar{A} \bar{l} / \bar{\mu} \zeta = 0$ . A singularity factor  $\xi^*$  is incorporated in the quantities associated with  $\zeta$ , where by definition  $\xi^*$  is identical to  $\xi$  in a segment adjoining a stagnation or sharp leading point or line and is any convenient positive constant or function of  $\xi$  and  $\eta$  elsewhere.

Finally  $w$  is eliminated by substituting its expression from Eq (6a) into the remainder of Eqs (6) yielding:

$$B_1 \frac{\partial v}{\partial \xi} + B_2 \frac{\partial v}{\partial \eta} + (B_3 + B_5) \frac{\partial v}{\partial \zeta} = B_3 \zeta \frac{\partial^2 v}{\partial \zeta^2} + B_6 \quad (7a)$$

$$B_1 \frac{\partial t}{\partial \xi} + B_2 \frac{\partial t}{\partial \eta} + (B_3 + B_5) \frac{\partial t}{\partial \zeta} = B_4 \zeta \frac{\partial^2 t}{\partial \zeta^2} + B_7 + B_9 \left( \frac{\partial v}{\partial \zeta} \right)^2 + B_{10} \left( \frac{\partial t}{\partial \zeta} \right)^2 + B_{11} \frac{\partial t}{\partial \zeta} \frac{\partial \varphi}{\partial \zeta} \quad (7b)$$

$$B_1 \frac{\partial \varphi}{\partial \xi} + B_2 \frac{\partial \varphi}{\partial \eta} + (-B_3 + B_5) \frac{\partial \varphi}{\partial \zeta} = B_3 \zeta \frac{\partial^2 \varphi}{\partial \zeta^2} + B_8 + B_{12} \frac{\partial v}{\partial \eta} + B_{13} \frac{\partial v}{\partial \zeta} + B_{14} \frac{\partial t}{\partial \xi} + B_{15} \frac{\partial t}{\partial \eta} + B_{16} \frac{\partial t}{\partial \zeta} \quad (7c)$$

$B_1 \dots B_{16}$  are differential coefficients defined as functions of the boundary conditions (surface geometry and inviscid flow properties), the transport properties of the fluid, and the non-dimensional quantities  $v$ ,  $t$ , and  $\varphi$ :

$$\begin{aligned} B_1 &= A_1 \zeta (1 - \zeta^2) & B_4 &= \frac{B_3}{P_r} \\ B_2 &= A_2 \zeta v & B_5 &= A_5 (1 - \zeta^2)^2 + A_6 (1 - \zeta^2) v - A_7 v^2 + A_8 t \\ B_3 &= A_4 \frac{v^2}{\mu} & B_6 &= \left[ A_9 (1 - \zeta^2)^2 - A_{10} (1 - \zeta^2) v - A_{11} v^2 - A_{12} t \right] \zeta \end{aligned}$$

$$B_7 = \left[ A_{13} (1 - \zeta^2) t + A_{14} v t + A_{15} \frac{\zeta^2 \varphi^2}{\mu} \right] \frac{\zeta}{c_p}$$

$$B_8 = - (B_3 + B_5) \frac{\varphi}{\zeta} + \left[ A_{17} (1 - \zeta^2) + A_{18} v \right] \zeta \varphi$$

$$B_9 = A_{16} \frac{\zeta \varphi^2}{\mu c_p}$$

$$B_{10} = \frac{B_4}{\kappa} \frac{\partial \kappa}{\partial t} \zeta$$

$$B_{11} = A_4 \left( \frac{1 - P_r}{P_r \mu} \right) \zeta \varphi$$

$$B_{12} = A_2 \zeta \varphi$$

$$B_{13} = \left[ A_6 (1 - \zeta^2) - 2 A_7 v \right] \varphi$$

$$B_{14} = B_1 \frac{\varphi}{\mu} \frac{\partial \mu}{\partial t}$$

$$B_{15} = B_2 \frac{\varphi}{\mu} \frac{\partial \mu}{\partial t}$$

$$B_{16} = \left( \frac{B_5}{\mu} \frac{\partial \mu}{\partial t} + A_8 \right) \varphi$$

For two dimensional flows the crossflow velocity  $V$ , and crossflow gradients  $\partial(\ )/\partial\eta$  are equal to zero.

In the three dimensional procedure, each boundary layer segment is replaced by a lattice of points with constant spacings  $a$ ,  $b$ ,  $c$  and integer indices  $i$ ,  $j$ ,  $k$  in the  $\xi$ ,  $\eta$ ,  $\zeta$  directions respectively. In Eqs (7a), (7b), and (7c), first order derivatives appear with respect to all three coordinates,  $\xi$ ,  $\eta$ , and  $\zeta$ ; second order derivatives appear only with respect to the  $\zeta$  coordinate. In the central difference approximation, the first derivative difference equations are written as:

$$\left[ \frac{\partial(\ )}{\partial \xi} \right]_{i,j,k} = \frac{1}{2a} \left[ (\ )_{i+1,j,k} - (\ )_{i-1,j,k} \right] \quad (8a)$$

$$\frac{\partial(\ )}{\partial \eta} \Big|_{i,j,k} = \frac{1}{2b} \left[ (\ )_{i,j+1,k} - (\ )_{i,j-1,k} \right] \quad (8b)$$

$$\frac{\partial(\quad)}{\partial \zeta} \Big|_{i,j,k} = \frac{1}{2c} \left[ (\quad)_{i,j,k+1} - (\quad)_{i,j,k-1} \right]. \quad (8c).$$

The errors introduced in this approximation are of the order of:

$$\frac{a^2}{6} \frac{\partial^3(\quad)}{\partial \xi^3} ; \quad \frac{b^2}{6} \frac{\partial^3(\quad)}{\partial \eta^3} ; \quad \frac{c^2}{6} \frac{\partial^3(\quad)}{\partial \zeta^3} \quad (9)$$

in Eqs (8a), (8b), and (8c) respectively. In a similar manner, the second derivative difference equation is written as:

$$\left[ \frac{\partial^2(\quad)}{\partial \zeta^2} \right]_{i,j,k} = \frac{1}{4c^2} \left[ (\quad)_{i,j,k+1} - 2(\quad)_{i,j,k} + (\quad)_{i,j,k-1} \right] \quad (10a)$$

The errors introduced in the approximation are of the order of:

$$\frac{c^2}{12} \frac{\partial^4(\quad)}{\partial \zeta^4}. \quad (11a)$$

This form of difference equation however, is usually numerically unstable for the parabolic type of equation (References 3, 9, 10). It was found in Reference 3 that numerical stability can be obtained if the second derivative difference Eq (10a) is rewritten as:

$$\left[ \frac{\partial^2(\quad)}{\partial \zeta^2} \right]_{i,j,k} = \frac{1}{4c^2} \left[ (\quad)_{i,j,k+1} - 2(\quad)_{i-1,j,k} + (\quad)_{i,j,k-1} \right]. \quad (10b)$$

The errors introduced in this approximation are of the order of:

$$\frac{c^2}{12} \frac{\partial^4(\quad)}{\partial \zeta^4} + \left( \frac{a}{c} \right)^2 \frac{\partial^2(\quad)}{\partial \xi^2}. \quad (11b)$$

The requirement for this approximation, therefore, is that:

$$a \ll c. \quad (12a)$$

Other conditions which must also be satisfied in this procedure are:

$$(1) \quad a, b, c \text{ are small in general} \quad (12b)$$

$$(2) \quad a \ll b \quad (12c)$$

$$(3) \quad a h_1 |v| \leq b h_2 u. \quad (12d)$$

Equations (7a), (7b), and (7c) therefore, can be written in the difference form by substituting Eqs (8a), (8b), (8c), and (10b) for the respective differentials.

$$\left(\frac{B_1}{2a} + k \frac{B_3}{c}\right) v_a = -\frac{B_2}{2b} v_b - \frac{(B_3 + B_5)}{2c} v_c + k \frac{B_3}{c} v_d + B_6 \quad (13a)$$

$$\begin{aligned} \left(\frac{B_1}{2a} + k \frac{B_4}{c}\right) t_a = & -\frac{B_2}{2b} t_b - \frac{(B_3 + B_5)}{2c} t_c + k \frac{B_4}{c} t_d + B_7 + \frac{B_9}{4c^2} v_c^2 \\ & + \frac{B_{10}}{4c^2} t_c^2 + \frac{B_{11}}{4c^2} t_c v_c \end{aligned} \quad (13b)$$

$$\begin{aligned} \left(\frac{B_1}{2a} + k \frac{B_3}{c}\right) v_a = & -\frac{B_2}{2b} v_b + \frac{(B_3 - B_5)}{2c} v_c + k \frac{B_3}{c} v_d + B_8 + \frac{B_{12}}{2b} v_b \\ & + \frac{B_{13}}{2c} v_c + \frac{B_{14}}{2a} t_a + \frac{B_{15}}{2b} t_b + \frac{B_{16}}{2c} t_c \end{aligned} \quad (13c)$$

where  $\xi$  has been replaced by  $ck$ , and:

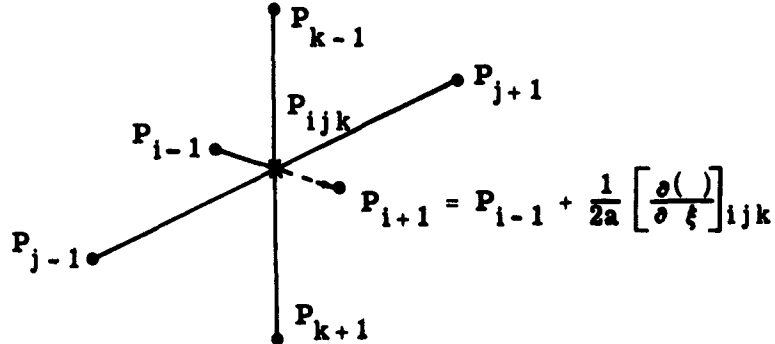
$$(\ )_a \equiv (\ )_{i+1,j,k} - (\ )_{i-1,j,k}$$

$$(\ )_b \equiv (\ )_{i,j+1,k} - (\ )_{i,j-1,k}$$

$$(\ )_c \equiv (\ )_{i,j,k+1} - (\ )_{i,j,k-1}$$

$$(\ )_d \equiv (\ )_{i,j,k+1} - 2(\ )_{i-1,j,k} + (\ )_{i,j,k-1}.$$

The numerical integration procedure is followed by a "leap-frogging" technique as described in Reference 3.



Consider the point  $P_{i,j,k}$  in the above sketch. The forward derivatives  $\frac{\partial(\ )}{\partial \xi}_{i,j,k}$  in the  $i$  direction at  $P_{i,j,k}$  are calculated by Eqs (13a), (13b) and (13c) using values from the five nearest neighboring points shown on the  $i$ th and  $(i-1)$ th planes. The value of the new point  $(\ )_{i+1,j,k}$  in the  $(i+1)$ th plane is calculated from the relation:

$$( )_{i+1,j,k} = ( )_{i-1,j,k} + \frac{1}{2a} \left[ \frac{\partial ( )}{\partial \xi} \right]_{i,j,k}$$

without calculating the value at  $P_{i,j,k}$ .

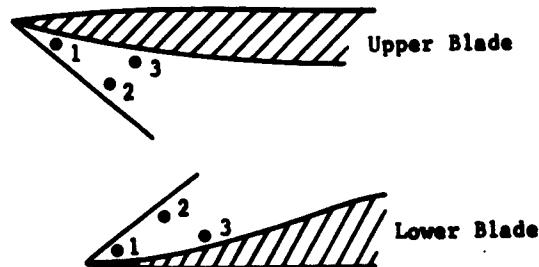
In this procedure, therefore, if the indices  $i, j, k$  start from 0,0,0, the forward derivatives are calculated from Eqs (13a), (13b), and (13c) when  $(i+j+k)$  is odd, and the values are calculated by Eq (14) when  $(i+j+k)$  is even.

#### IV PROGRAM CONSTRUCTION

This program contains ten chains for the various phases of computation. Figure 18 is an overall diagram showing the linkage of the system. The functions of each chain are as follows:

##### CHAIN I

Chain I reads in the first data card which contains a blade type indicator; free stream Mach number, pressure, and temperature; and the specific heat ratio. These data are stored on tape 2 for use by the entire program. If a blunt leading edge case is indicated, Chain VII is immediately called to calculate the flow field ahead of the blunt noses. If a sharp leading edge case is indicated, the wedge program is used to determine three initial field points for each surface as shown in the following sketch.



The calculation of these points are controlled by Subroutine WEDGE. The first point (1) is calculated by Subroutine SHK1, and the other two Points (2) and (3) are calculated by a special shock-body subroutine (Subroutine SHOCK). The procedure of calculation used in these routines are described in Appendix A.

The blade geometry data are then read from cards, and the surface data are fitted with a series of cubics using Subroutines CURFIT and CUBIC. The coefficients of these fitted equations are stored on tape 2 for later use in the program.

##### CHAIN VII:

Chain VII calculates the flow about a cylindrical body of unit radius by a 2nd order Belotserkovskii procedure. This chain determines the data along an initial value line in a radial direction from the body center of curvature to the shock.

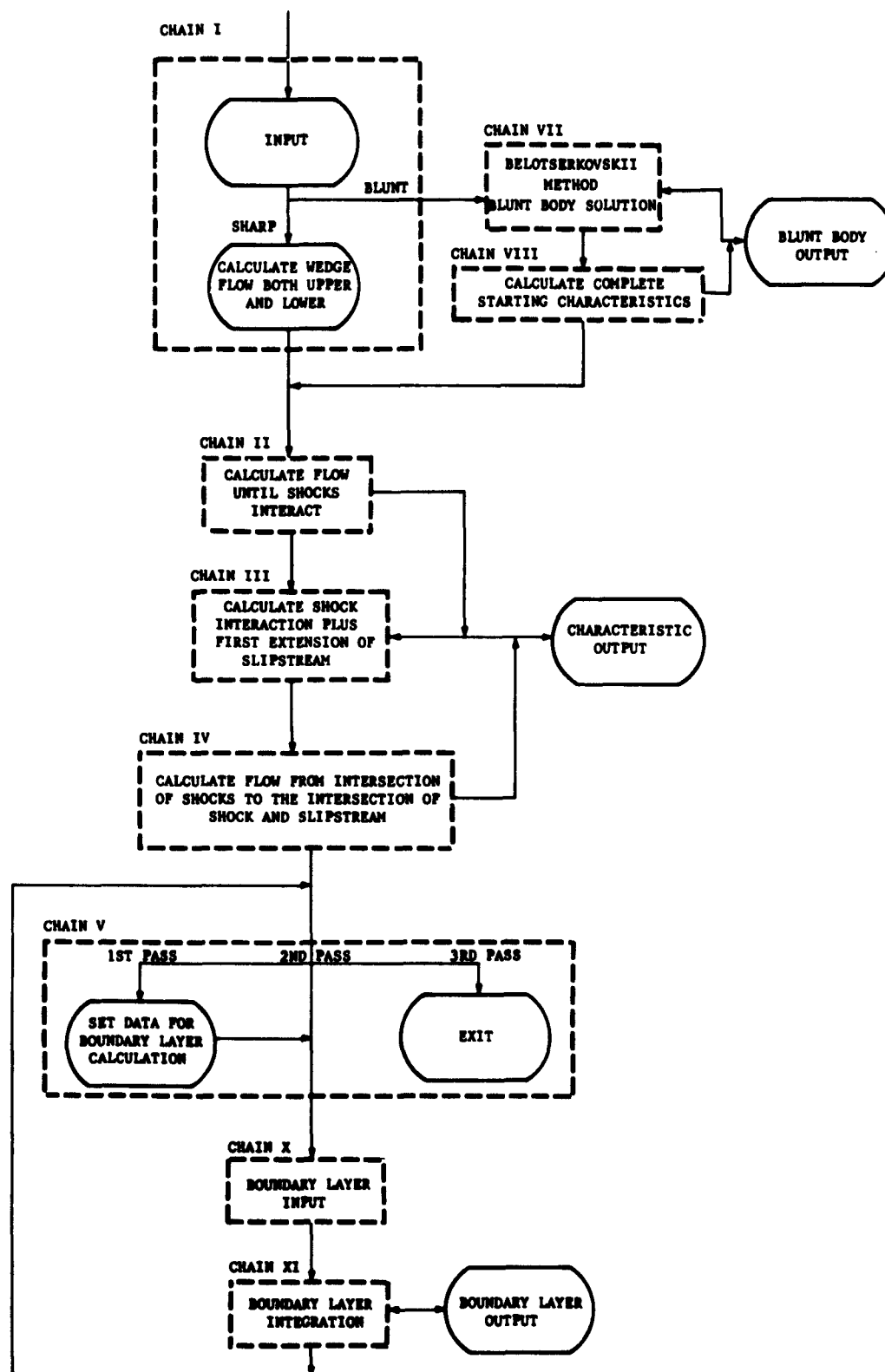
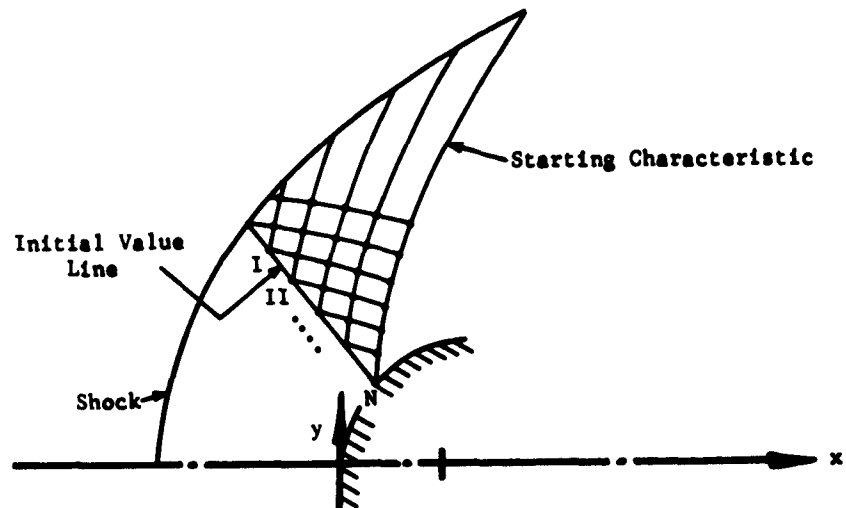


FIGURE 10 PROGRAM CONSTRUCTION DIAGRAM

#### CHAIN VIII

This chain uses the initial value line obtained in Chain VII and calculates a complete left running characteristic from body to shock, as shown in the following sketch.



The calculation starts at the shock. Characteristic I is first calculated, then II, etc., until a complete characteristic from the body to the shock is obtained. This starting characteristic can be used for the upper and lower blade surfaces by proper data transformation.

The blade geometry data are then read from cards. The starting characteristics just calculated are dimensionalized with the given body leading edge radius. The blade geometry data are then curve fitted, merging smoothly to the cylindrical blunt leading edge sections. The coefficients of the body description equations are stored on tape 2 for later use in the program.

#### CHAIN II

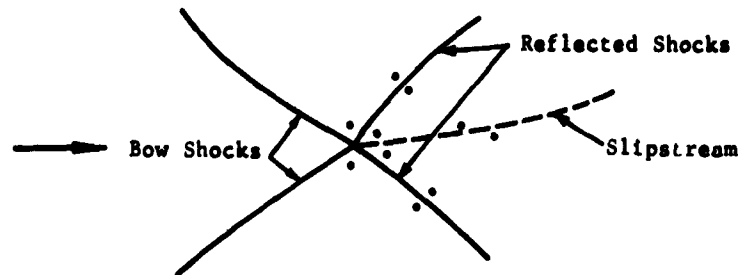
This chain calculates the flow field of the upper and lower blade surfaces using the starting characteristics calculated in Chain I or Chain VIII, and continuing until the two bow shocks cross (Figure 2).

#### CHAIN III:

Chain III calculates the interaction of shocks of opposite families. The location of the interaction point is calculated by a curve fit method for intersecting two curves (Subroutine MEET).

The properties behind each shock are calculated by Subroutine SHK1, and the slip-stream deflection and the properties behind each of the reflected shocks are calculated by an iteration procedure which is discussed in Appendix A.

Next, the first extensions of the reflected shock waves and slipstream are calculated. The sketch below shows the points being calculated in this chain.



CHAIN IV:

This chain controls the remaining characteristic calculation, which includes the slipstream, shock-body interactions, and shock-slipstream interactions.

CHAIN V:

This chain reads the characteristic data from tapes 3 and 4 and calculates the surface velocity vs surface distance data. These data are then written on tape 9 for the boundary layer calculation.

CHAIN X:

Chain X is the boundary layer input program which calculates the "A" coefficients from the surface velocity data. These coefficients are the input data for the boundary layer integration program.

CHAIN XI:

Chain XI is the boundary layer integration program which calculates properties across the boundary layer (velocity, temperature and shear profiles). From these properties, the boundary layer thickness and skin friction, etc., are calculated.

## V SAMPLE RESULTS AND DISCUSSION

Three sample cases have been calculated. The flow in a sharp leading-edge channel was calculated for incident flows of Mach 4 and Mach 6 while only a Mach 4 case was calculated for a blunt leading-edge channel. The calculated flow geometry for these three cases are shown in Figures 4, 5, and 6. For the two sharp leading-edge cases, inviscid flow fields were calculated up to and including the shock-slipstream interaction point. For the blunt leading-edge case, however, the calculation could not be carried as far, due to the fact that adjacent characteristics overlapped, which indicates that envelope shocks are being formed in this region. As yet an envelope shock routine has not been developed. The reason for the envelope shock formation is due, of course, to the particular channel geometry selected. These results show that an envelope shock subroutine is needed to complete the present type of flow field calculation.

The sharp leading-edge geometry selected for calculation has  $20^\circ$  and  $15^\circ$  leading-edge angles on the lower and upper surfaces, respectively. The initial shock strength, therefore, is higher on the lower surface. Also, because the flow along the lower surface is being compressed while the flow along the upper surface is being expanded, the lower shock strength will be even stronger at the shock interaction point. When two shocks of different strengths interact, the resulting flow is deflected toward the side generating the weaker shock. For the Mach 4 and Mach 6 cases, the flow deflection angle was found to be about  $7^\circ$  and  $8^\circ$ , respectively. The general flow pattern for the two cases are similar except that at the point of shock-slipstream interaction, a compression wave was created for the Mach 4 case, while for the Mach 6 case, an expansion wave was created. These waves were found to be extremely weak and can be neglected in the downstream flow field calculation. Although the calculations have not been carried farther downstream, the shock shapes indicated that interaction of shocks of the same family is likely to occur only slightly downstream of the last computations. This is due to the fact that the deflected shocks from the upper surface extend much farther downstream than those of the lower surface.

Because the flows are being expanded near the upper surface and the flows are being compressed near the lower surface, large pressure gradients exist across the channel during the turning process. Figures 7 to 10 show the pressure and Mach number distribution along the upper and lower surfaces for the two sharp leading edge cases, and Figure 11 shows the pressure variation across the channel at various longitudinal stations for the  $M=6$  case only.

A blunt leading-edge radius of 1.0 was selected for the blunt leading-edge channel geometry. The incident angle  $\alpha$  for this channel is about  $13.75^\circ$  (Figure 6). For the selected body shape, the flow has turned to an angle of approximately  $30^\circ$  before two adjacent characteristics overlapped.

The laminar boundary layers were calculated for the two sharp leading-edge cases. The boundary layer displacement thickness distributions are plotted in Figures 12 and 13, (note that the vertical scale has been highly magnified). The calculations show that for both cases the boundary layer on the lower surfaces had separated at about the same longitudinal station -  $X = 10.0$  for the Mach 4 case and  $X = 10.65$  for the Mach 6 case. These boundary layer separation points are also indicated in Figures 4, 5, 7 and 8. Separation occurs at the point where the shear, which is proportional to the velocity derivative  $du'/ds'$  at the wall, becomes zero. Some velocity and shear profiles along the lower surfaces

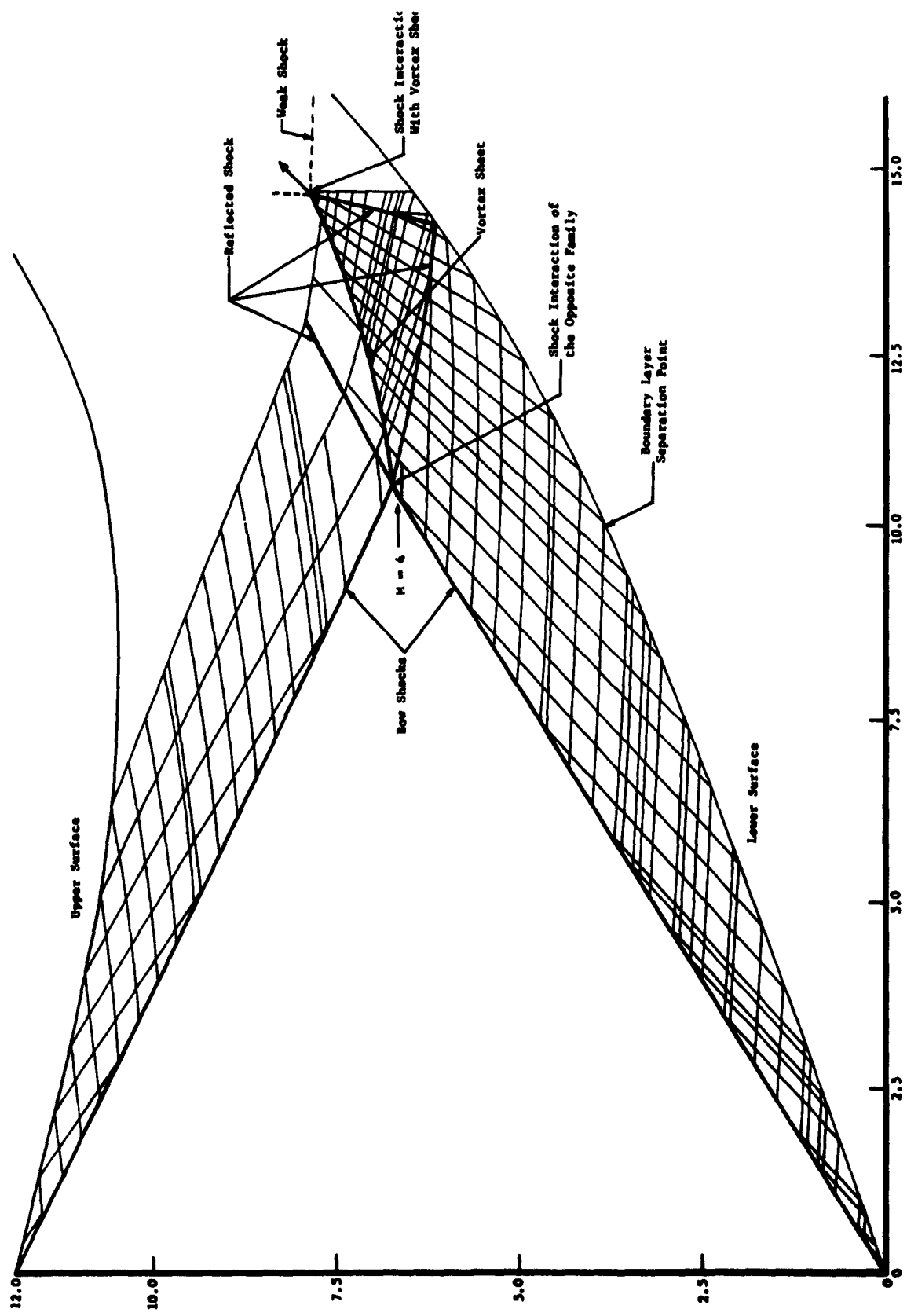


FIGURE 4 INVISCID FLOW FIELD FOR A SHARP LEADING-EDGE CURVED CHANNEL  $M_\infty = 4.0$

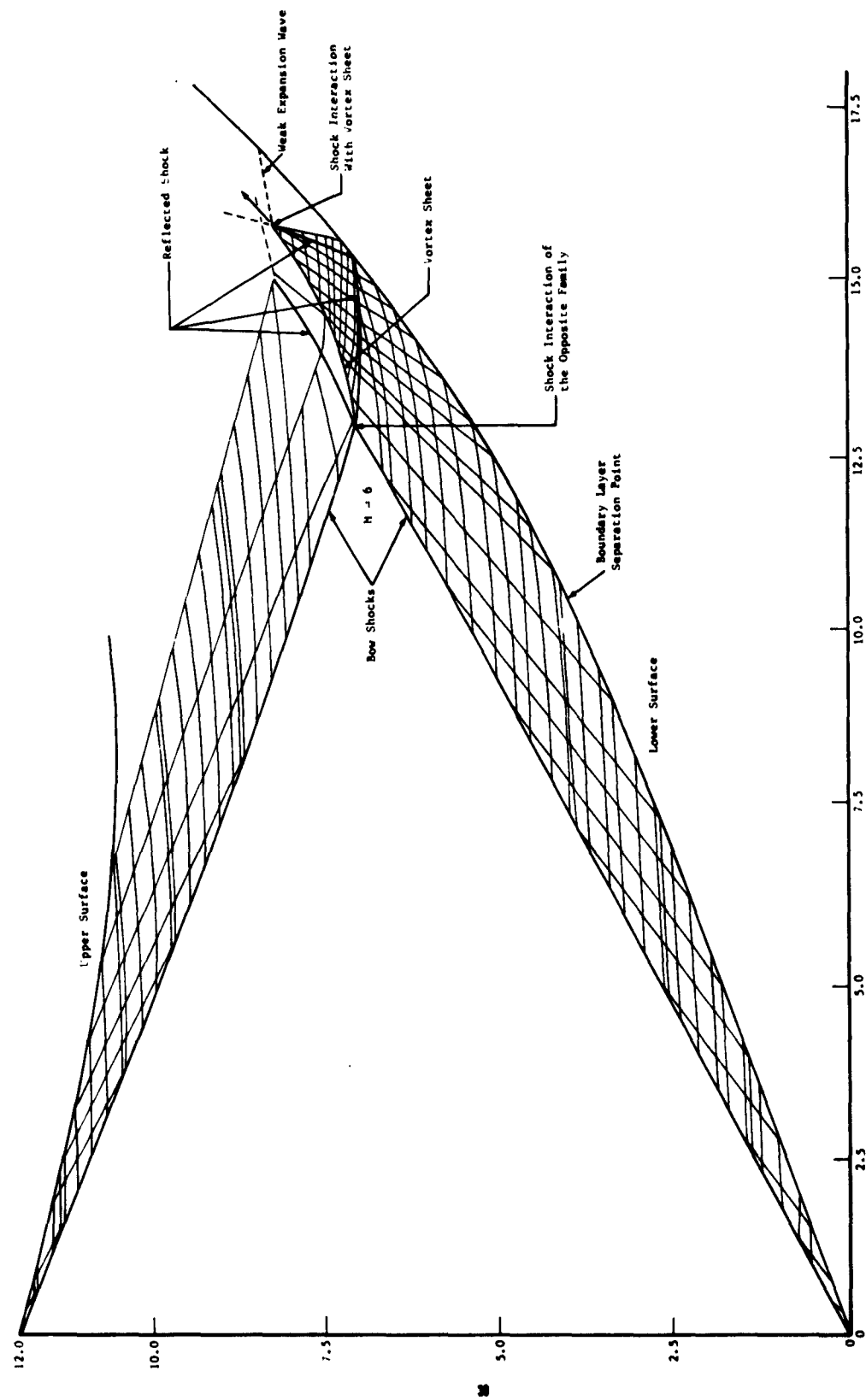


FIGURE 5 INVISCID FLOW FIELD FOR A SHARP LEADING-EDGE CURVED CHANNEL  $M_\infty = 6.0$

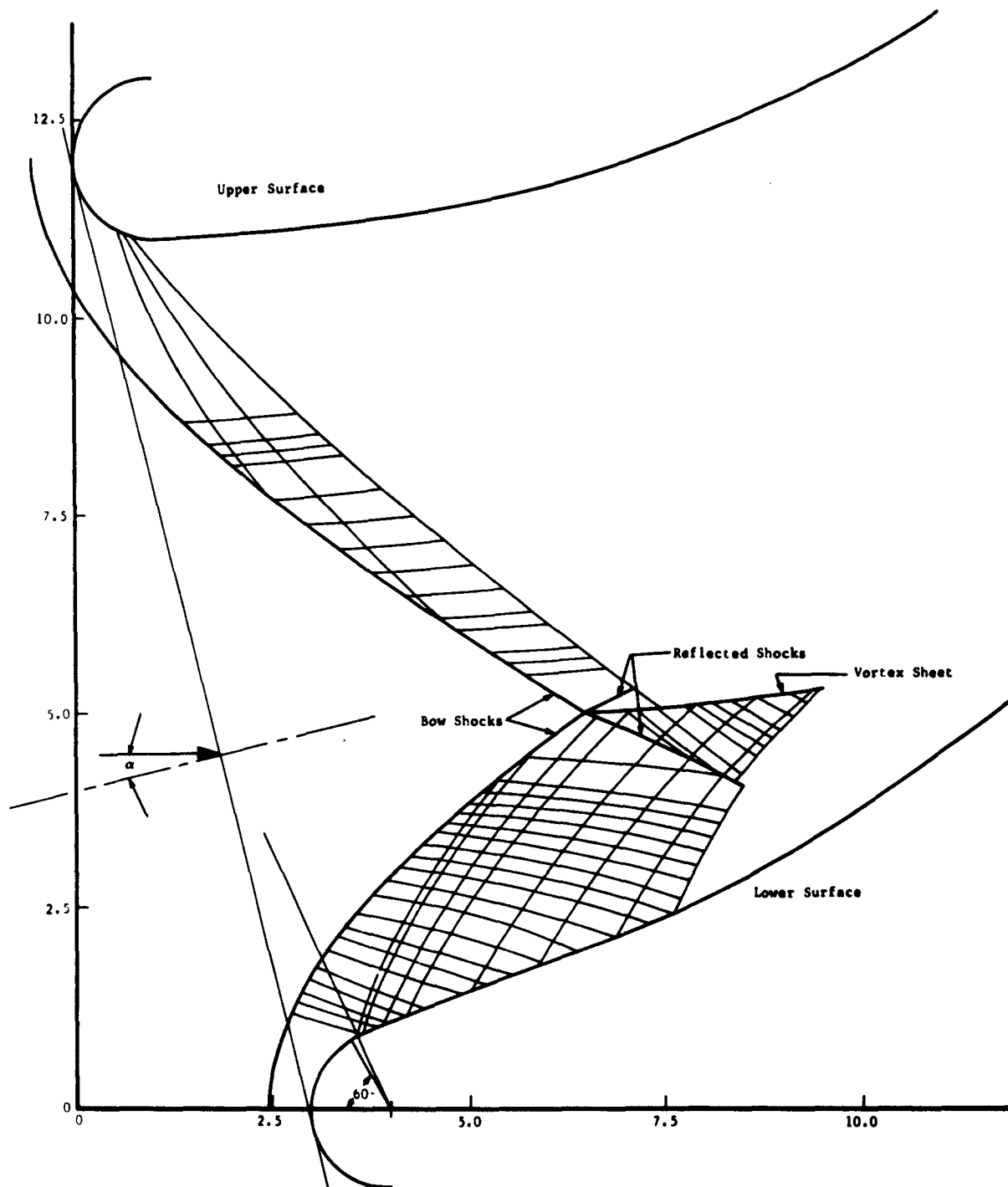


FIGURE 6 INTERNAL FLOW FIELD OF A BLUNT LEADING EDGE CHANNEL

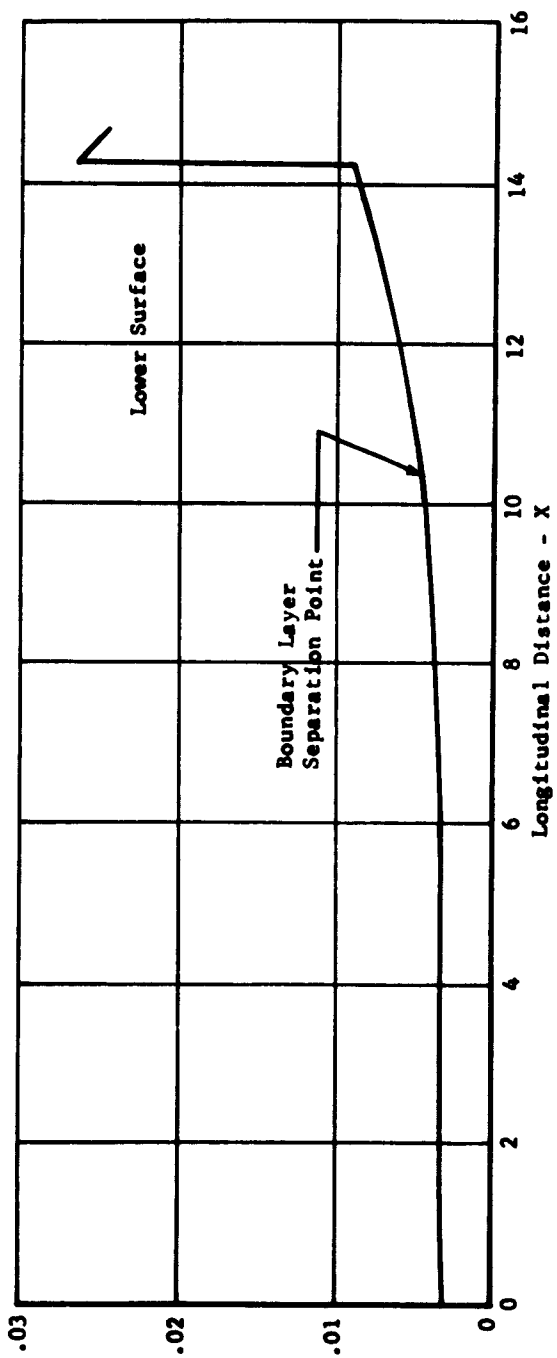
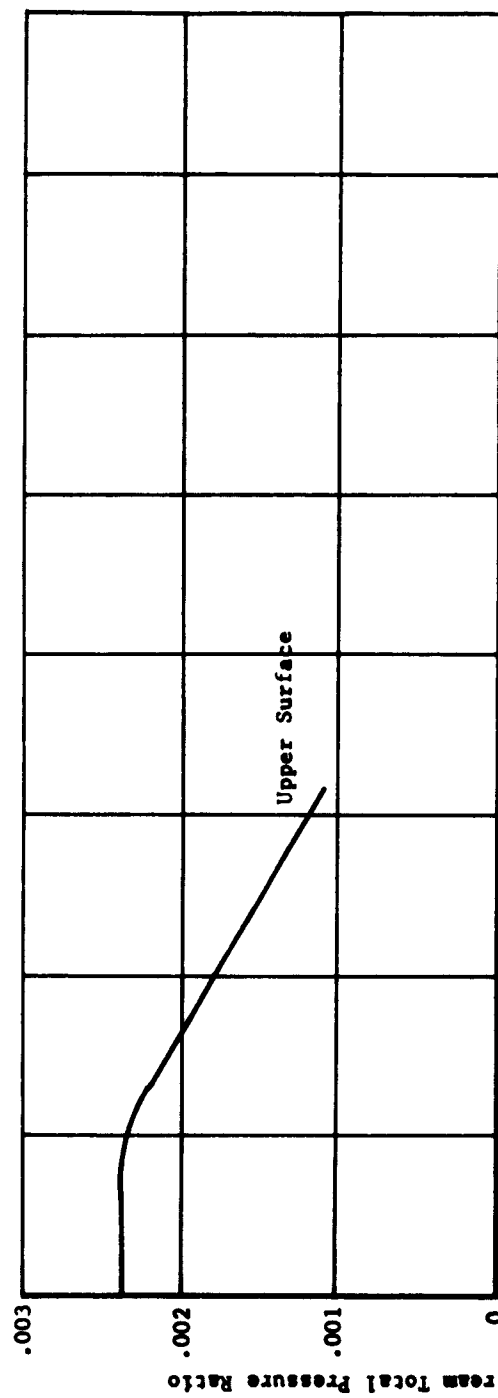


FIGURE 7 PRESSURE DISTRIBUTION ALONG THE SURFACES OF A SHARP LEADING-EDGE CHANNEL  $M_{\infty} = 4.0$

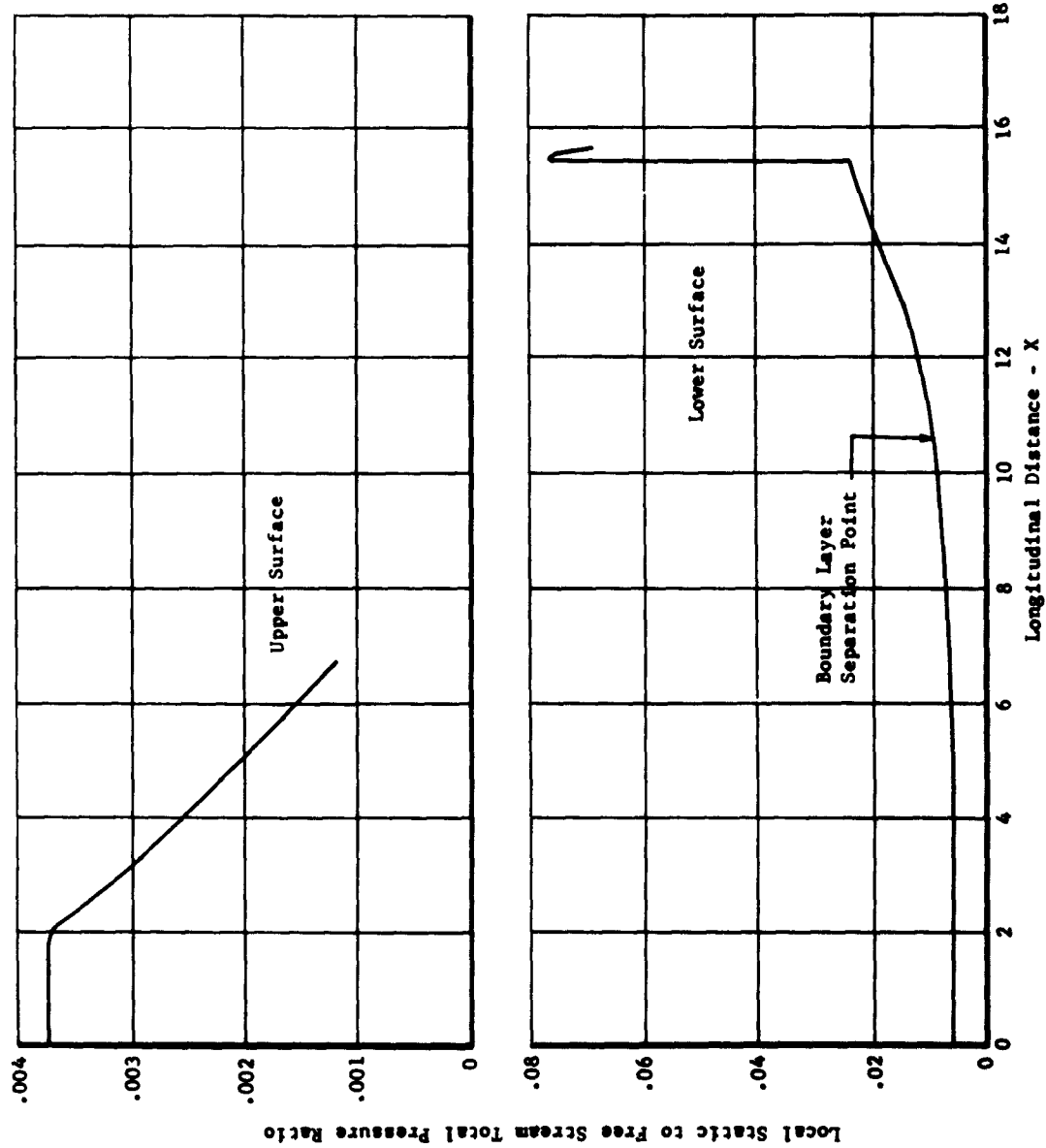


FIGURE 8 PRESSURE DISTRIBUTION ALONG THE SURFACES OF A SHARP LEADING-EDGE CHANNEL  $M_\infty = 6.0$

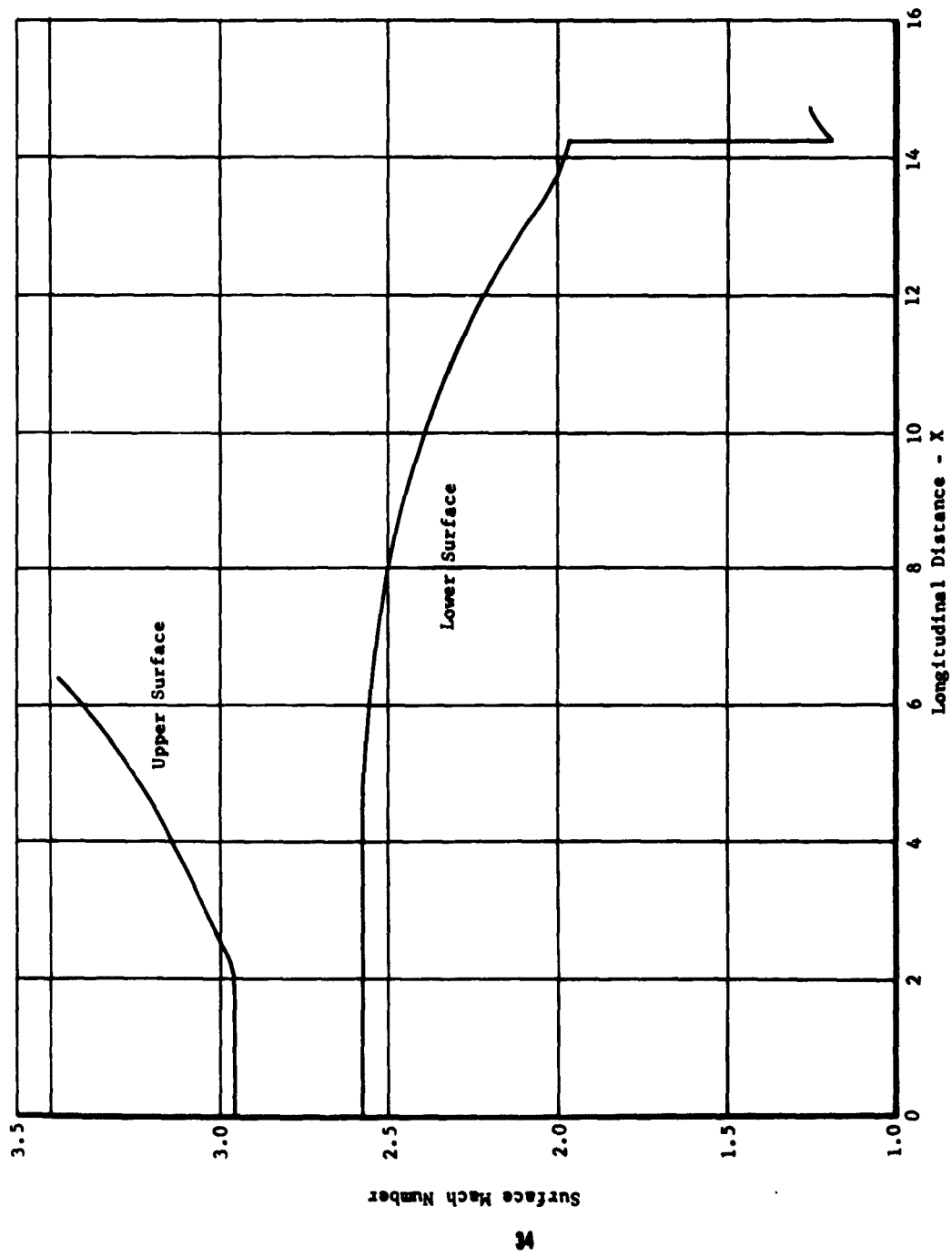


FIGURE 9 MACH NUMBER DISTRIBUTION ALONG THE SURFACES OF A SHARP LEADING-EDGE CHANNEL  $M_{\infty} = 4.0$

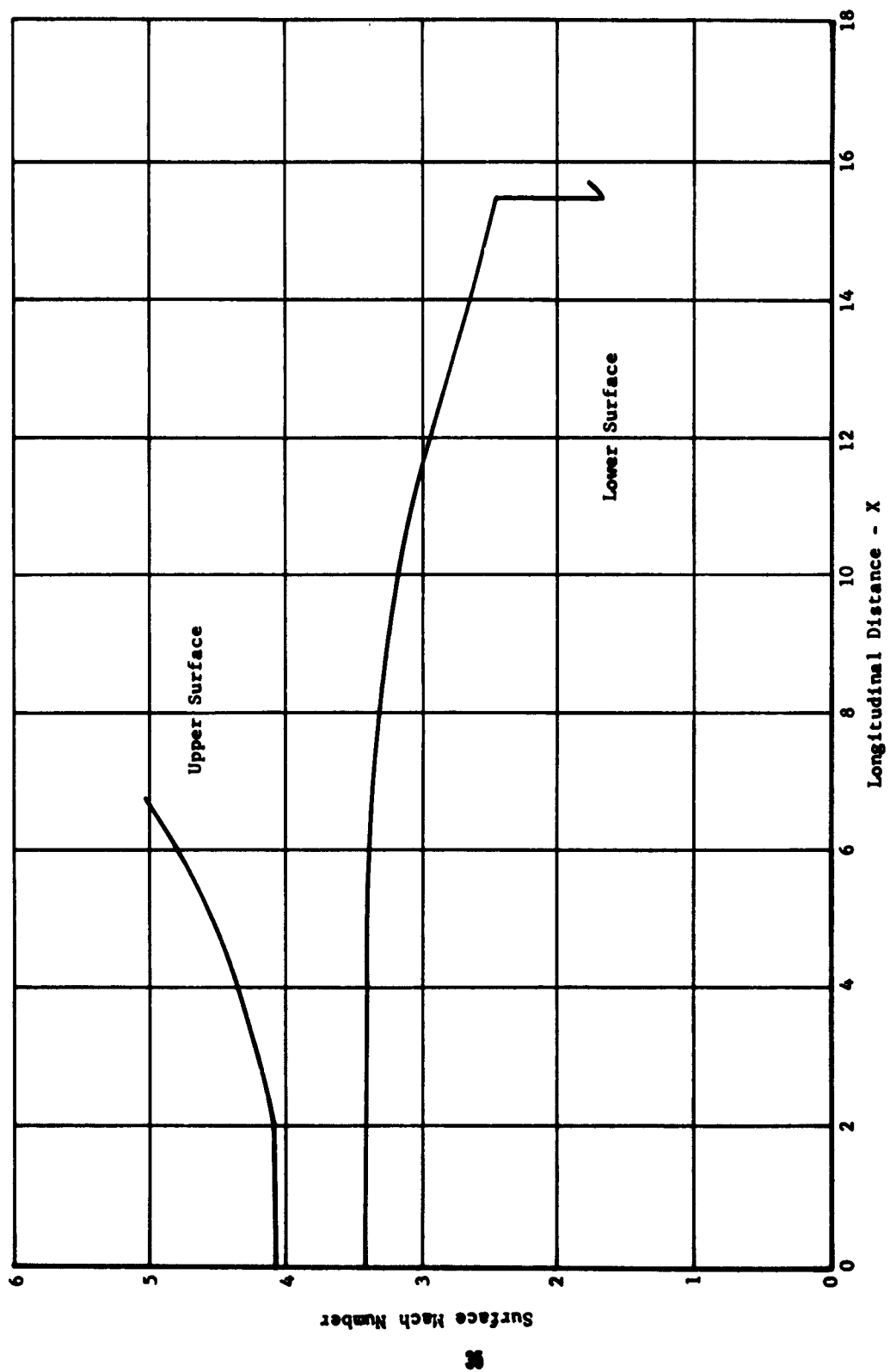


FIGURE 10 MACH NUMBER DISTRIBUTION ALONG THE SURFACES OF A SHARP LEADING-EDGE CHANNEL  $M_{\infty} = 6.0$



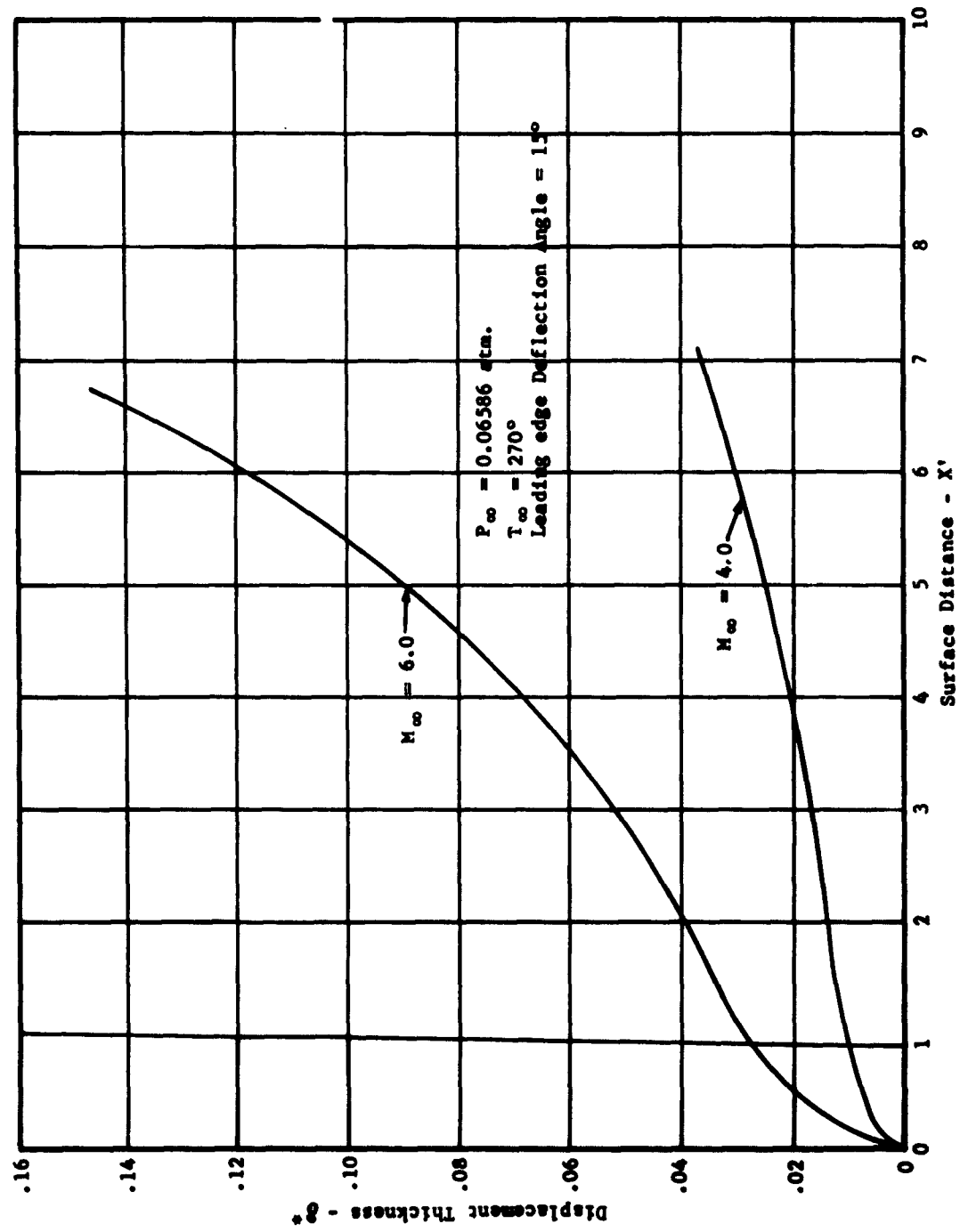


FIGURE 12 BOUNDARY LAYER DISPLACEMENT THICKNESS DISTRIBUTION ON THE UPPER (EXPANSION) SURFACE OF A SHARP LEADING-EDGE CHANNEL

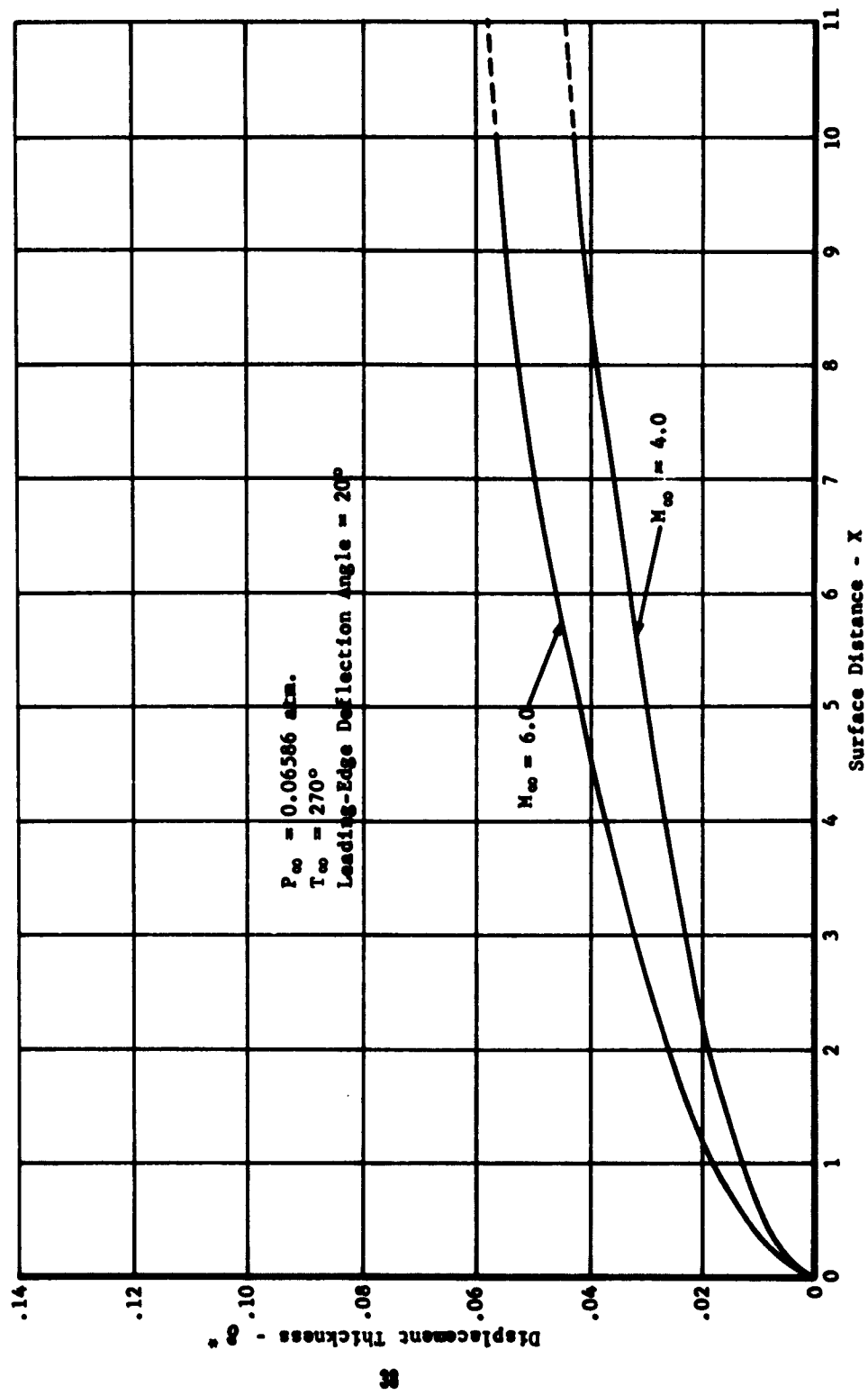


FIGURE 13 BOUNDARY LAYER DISPLACEMENT THICKNESS DISTRIBUTION ON THE LOWER (COMPRESSION) SURFACE OF A SHARP LEADING-EDGE CHANNEL

are plotted in Figures 14 to 17. The separation points indicated on the pressure distribution curves in Figures 7 and 8 show that the boundary layer separates even with a very weak adverse pressure gradient. This indicates that in order to maintain a non-separated boundary layer, the pressure gradient must be kept small. To do this, however, a very long channel is required in order to obtain a reasonably high flow turning angle. A more practical solution which should be investigated in the future, is to use boundary layer suction so that the wall shear values can be controlled externally.

In view of the results obtained with this program, the following conclusions can be drawn:

1. To calculate the complete internal inviscid flow field with turning, two additional IBM subroutines are needed; (a) envelope shock, and (b) interactions of shocks of the same family.
2. Boundary layer on the compression surface can be easily separated by the adverse pressure gradient. Boundary layer suction may be needed to maintain an attached boundary layer.

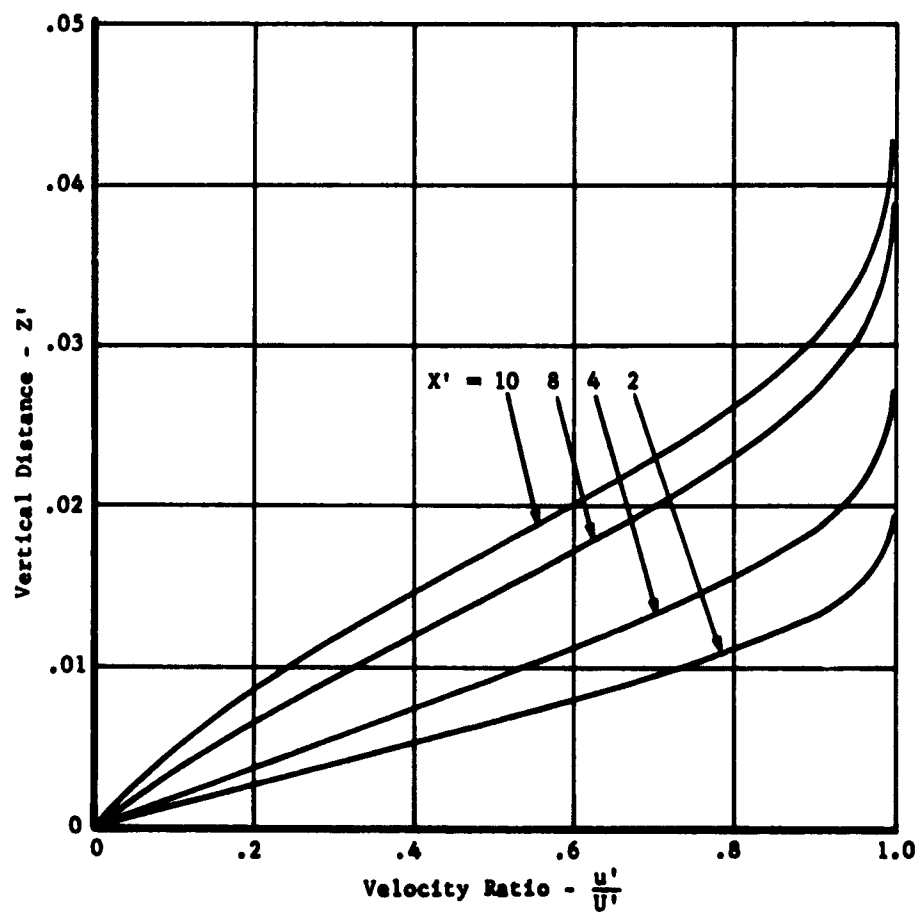


FIGURE 14 VELOCITY PROFILES ALONG THE LOWER (COMPRESSION) SURFACE OF A SHARP LEADING-EDGE CHANNEL  $M_\infty = 4.0$

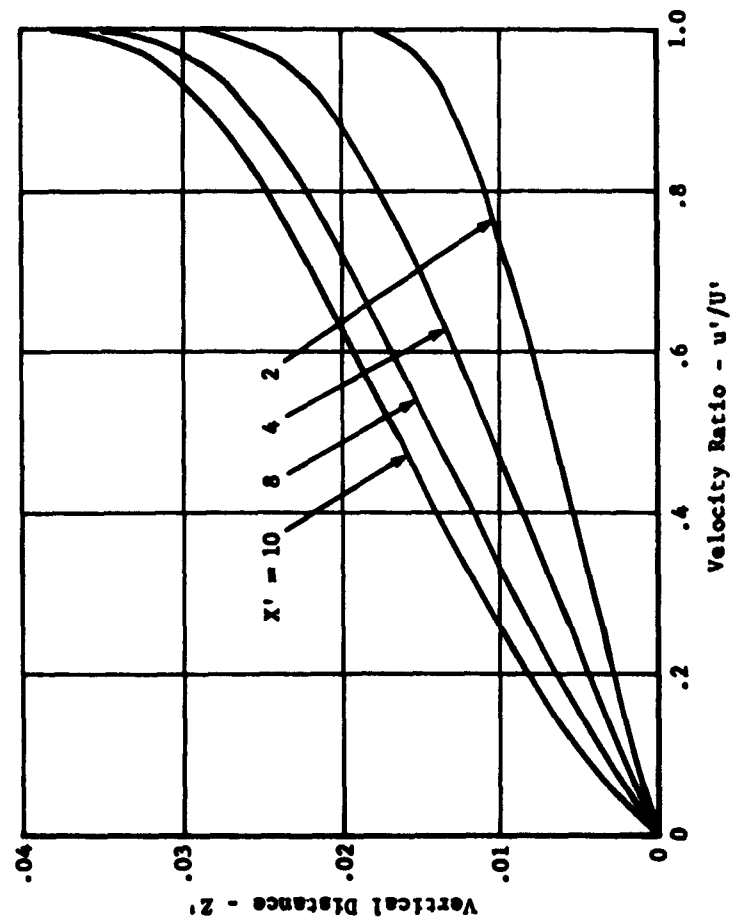


FIGURE 15 BOUNDARY LAYER VELOCITY PROFILES ALONG THE COMPRESSION SURFACE OF A SHARP LEADING-EDGE CHANNEL  $M_\infty = 6.0$

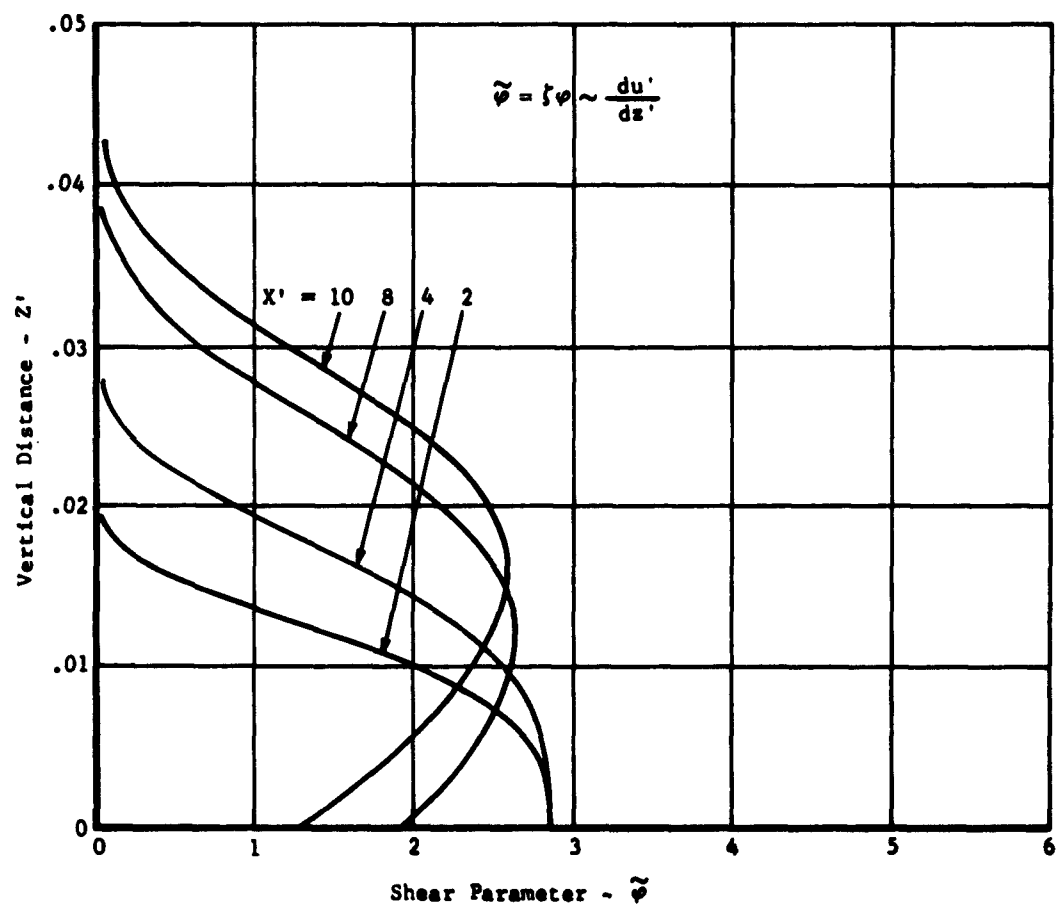


FIGURE 16 BOUNDARY LAYER SHEAR PROFILES ALONG THE COMPRESSION SURFACE OF A SHARP LEADING-EDGE CHANNEL  $M_\infty = 4.0$

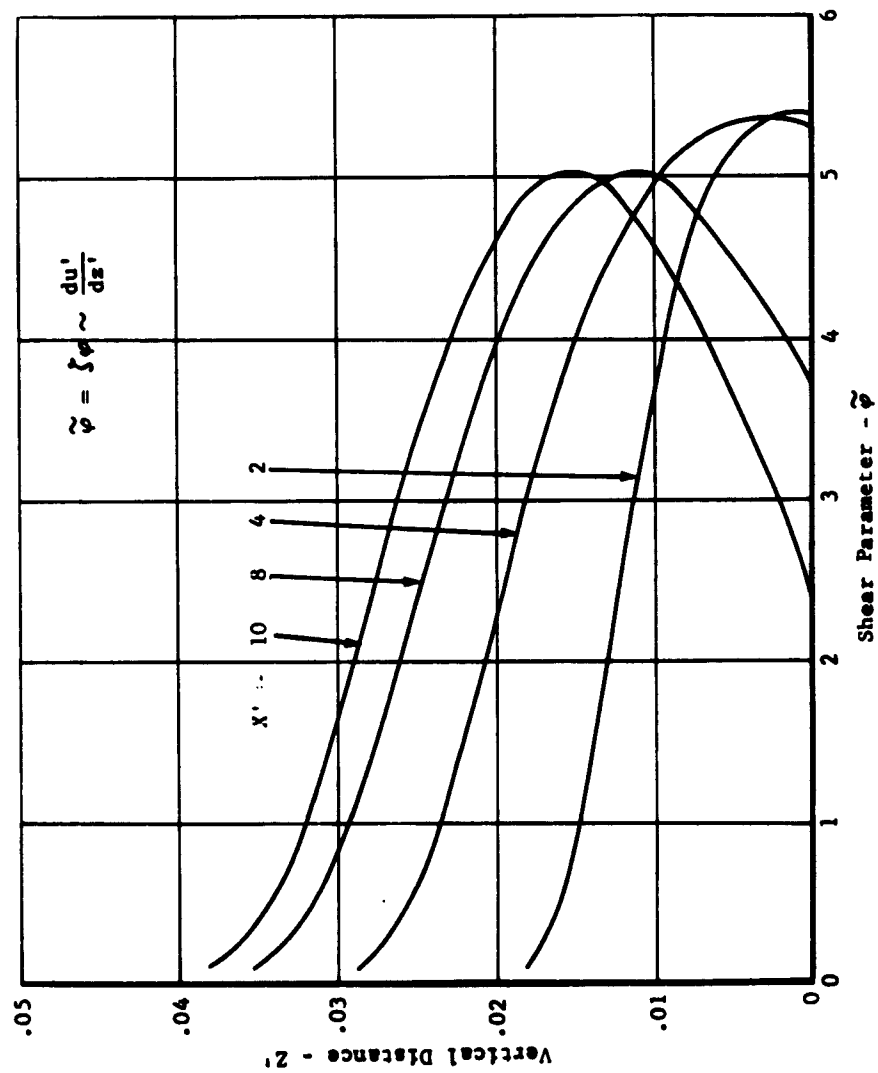


FIGURE 17 BOUNDARY LAYER SHEAR PROFILES ALONG THE COMPRESSION SURFACE OF A SHARP LEADING-EDGE CHANNEL  $M_\infty \approx 6.0$

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**APPENDIX A**

**SHOCK POINT CALCULATION**

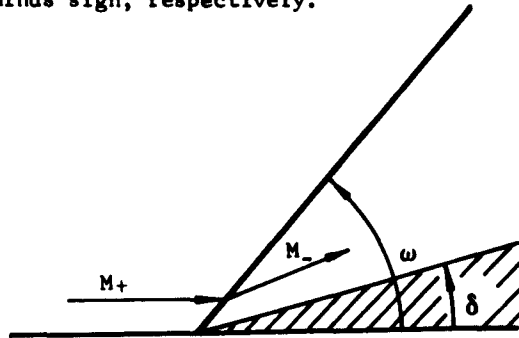
## APPENDIX A

### SHOCK POINT CALCULATION

Two major shock subroutines are used for most of the shock point calculations. One is for an oblique shock calculation which is used to initiate a shock wave at a point of discontinuity in flow direction. The other is for a general field shock calculation which is used to extend a shock from a previously calculated shock segment. There are special cases, however, such as the shock-boundary interaction and shock-slipstream interaction, where modifications of these two basic methods must be made. The two major shock routines are described in detail in this appendix and the differences for the special cases are outlined.

#### OBLIQUE SHOCK ROUTINE

In the following, quantities ahead of and behind the shock will be denoted by a subscript plus or minus sign, respectively.



The oblique shock routine calculates a shock angle  $\omega$  from a given wedge or flow deflection angle  $\delta$ . With a known incident Mach number  $M_+$  and the fluid specific heat ratio  $\gamma$ ,  $\omega$  and  $\delta$  are related through

$$\cot \delta = \tan \omega \left[ \frac{(\gamma + 1) M_+^2}{2(M_+^2 \sin^2 \omega - 1)} - 1 \right] \quad \text{A-1}$$

Eq. A-1 is a transcendental equation in  $\omega$ , and an iterative solution must be used. Using the Newton iteration procedure,  $\omega$  is calculated by

$$\omega_{i+1} = \omega_i + \frac{\delta - \delta_i}{\frac{d\delta_i}{d\omega_i}} \quad \text{A-2}$$

Where subscript  $i$  denotes the  $i^{\text{th}}$  cycle of iteration, and

$$\frac{d\delta}{d\omega} = \frac{2\cos^2\delta}{M_+^2(\gamma + \cos 2\omega) + 2} \left[ \frac{M_+^2 \cos 2\omega + \frac{1}{\sin^2\omega}}{\sin^2\omega} + (M_+^2 \sin 2\omega - 2\cot\omega) \left( \frac{M_+^2 \sin 2\omega}{M_+^2(\gamma + \cos 2\omega) + 2} \right) \right] . \quad \text{A-3}$$

Here  $\omega_{i+1}$  represents a new approximation to the shock angle. To start the calculation, the first approximation to the shock angle is taken to be the incident Mach angle, i.e.,

$$\omega_0 = \tan^{-1} \left( \frac{1}{M_+^2 - 1} \right)^{1/2} . \quad \text{A-4}$$

The general oblique shock calculation procedure can be summarized as follows:

1. Assume a shock angle  $\omega_0$  (Eq. A-4)
2. Calculate a  $\delta_1$  by Eq. A-1
3. Check the accuracy by comparing  $\delta_1$  with  $\delta$ .  $|\delta - \delta_1| \geq 10^{-5}$  is generally considered as satisfactory.
4. When the accuracy check is satisfied, the solution is converged; otherwise, a new shock angle  $\omega_{i+1}$  is computed (Eq. A-2).
5. Go back to Step (2) and repeat the calculation until convergence occurs in Step (4).

Equation A-1 contains two roots in  $\omega$ ; one corresponds to a weak shock solution, and the other corresponds to a strong shock solution. Only the weak shock solution has meaning here. For a given set of  $M_+$  and  $\gamma$ , the desired root of Eq. A-1 will be in the range

$$\omega_0 \leq \omega < \omega_{\max} .$$

Where  $\omega_{\max}$  is the shock wave angle for which  $M_- = 1.0$ . Similarly,  $\delta_{\max}$  is the deflection angle corresponding to  $\omega_{\max}$ .

$$\delta_{\max} = \tan^{-1} \left[ \frac{M_+^2 \sin(2\omega_{\max}) - 2\cot(\omega_{\max})}{M_+^2 [\gamma + \cos(2\omega_{\max})] + 2} \right] , \quad \text{A-5a}$$

where

$$\omega_{\max} = \frac{1}{4\gamma M_+^2} \left\{ (\gamma+1) M_+^2 - 3 - \gamma + \sqrt{(\gamma+1) \left[ (\gamma+1) M_+^4 - 2(3-\gamma) M_+^2 + (\gamma+9) \right]} \right\} \quad A-5b$$

It is necessary therefore, to first calculate  $\delta_{\max}$  to make certain that  $\delta < \delta_{\max}$ . Also, since  $d\delta/d\omega$  approaches infinity at  $\delta_{\max}$ ,  $d\delta/d\omega$  in Eq. A-2 is arbitrarily restricted to a maximum value of 1.0 during iteration.

With  $\omega$  calculated, flow properties immediately behind the shock can be determined directly. These properties are:

1. Static pressure

$$P_- = P_+ \left[ \frac{2\gamma M_+^2 \sin^2 \omega - (\gamma-1)}{\gamma+1} \right] \quad A-6$$

2. Total pressure

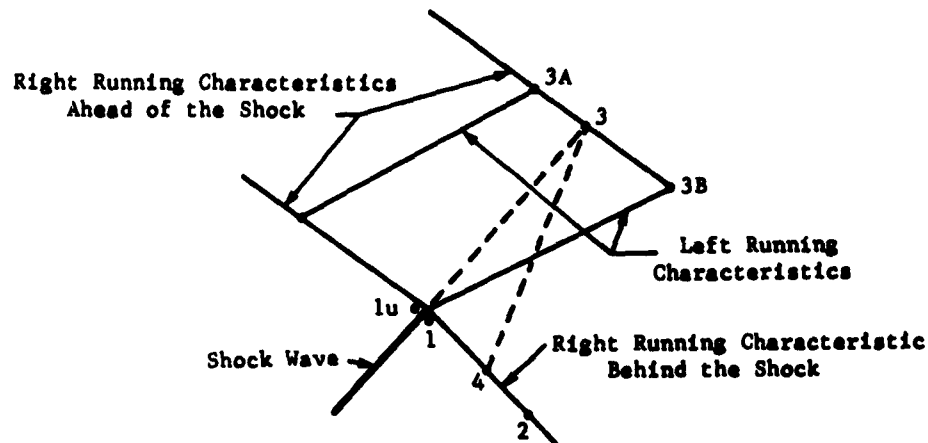
$$R_- = R_+ \left[ \frac{(\gamma+1) M_+^2 + \sin^2 \omega}{(\gamma-1) M_+^2 \sin^2 \omega + 2} \right]^{\frac{\gamma}{\gamma-1}} \times \left[ \frac{\gamma+1}{2\gamma M_+^2 \sin^2 \omega - (\gamma-1)} \right]^{\frac{1}{\gamma-1}} \quad A-7$$

3. Mach number

$$M_-^2 = \frac{2}{\gamma-1} \left[ \left( \frac{R_-}{P_-} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right] \quad A-8$$

#### GENERAL FIELD SHOCK CALCULATION

The general field shock routine calculates extensions of an existing shock wave. The flow field immediately ahead of the shock can be either uniform or non-uniform. The shock wave calculated in a uniform field is a bow wave and the shock wave calculated in a non-uniform field is a secondary wave.



In the sketch above, a shock wave segment is to be inserted from 1 to 3. A double iteration procedure is required to calculate the shock angle  $\omega$  and the flow direction  $\theta$  at 3. The general iteration procedure is as follows:

First assume a linear extension of the shock wave at Point 1 to approximate the location of Point 3, which lies between 3A and 3B. Then by interpolation, using the data at 3A and 3B, and the oblique shock relation, the incident and the transmitted shock properties at 3 can be determined. The results are then checked with the compatibility equation along a right running characteristic from 3 to 4. Point 4 is also an interpolated point, which in this case lies between Points 1 and 2.

The calculation for both cases (bow or secondary wave) is similar except that for the case of the bow wave, the locations of Points 3A and 3B have not been previously established, but the flow properties are known (free stream conditions). So, for the case of the bow wave, Points 3A and 3B are determined by

$$X_{3A} = X_3 - \frac{\beta}{2} \cos(-\mu_{3A})$$

$$Y_{3A} = Y_3 + \frac{\beta}{2} \sin(-\mu_{3A})$$

$$X_{3B} = X_3 + \frac{\beta}{2} \cos(-\mu_{3A})$$

$$Y_{3B} = Y_3 + \frac{\beta}{2} \sin(-\mu_{3A})$$

A-9

where

$$\mu_{3A} = \tan^{-1} \left[ \frac{1}{M^2 - 1} \right]^{1/2}$$

$\omega_3$  and  $(\theta_+)_3$  are related by the equation

$$\frac{Y_3 - Y_1}{X_3 - X_1} = \tan(\omega \pm \theta_+) \frac{1}{1, 3}$$

$y_3$  can be eliminated by writing

$$\frac{Y_3 - Y_{3A}}{X_3 - X_{3A}} = \tan(\theta \pm \mu) \frac{3A, 3B}{3A, 3B} ,$$

so that

$$X_3 = \frac{Y_{3A} - Y_1 + X_1 \tan(\theta_+ \pm \omega) \frac{1}{1, 3} - X_{3A} \tan(\theta \pm \mu) \frac{3A, 3B}{3A, 3B}}{\tan(\theta_+ \pm \omega) \frac{1}{1, 3} - \tan(\theta \pm \mu) \frac{3A, 3B}{3A, 3B}} . \quad A-10$$

Eq. A-10 related  $X_3$  and  $(\theta_+)_3$  for an assumed  $\omega_3$ . Since all incident shock properties at 3 are interpolated, it is convenient to calculate the ratio  $RR1 = (X_3 - X_{3A}) / (X_{3B} - X_{3A})$  directly by the Newton iteration procedure. Thus,

$$f(RR1) = RR1 + \frac{Y_{3A} - Y_1}{Y_{3B} - Y_{3A}} - \left( RR1 + \frac{X_{3A} - X_1}{X_{3B} - X_{3A}} \right) \frac{X_{3B} - X_{3A}}{Y_{3B} - Y_{3A}} \left[ \tan \left[ \frac{\pm(\omega_3 + \omega_1) + \theta_{1u} + \theta_{3A}}{2} + RR1 \frac{\theta_{3B} - \theta_{3A}}{2} \right] \right] . \quad A-12$$

With  $RR1$  calculated, the incident properties can be determined by

$$\begin{aligned} X_3 &= X_{3A} + RR1(X_{3B} - X_{3A}) \\ Y_3 &= Y_{3A} + RR1(Y_{3B} - Y_{3A}) \\ (P_+)_3 &= P_{3A} + RR1(P_{3B} - P_{3A}) \\ (\theta_+)_3 &= \theta_{3A} + RR1(\theta_{3B} - \theta_{3A}) \\ (\mu_+)_3 &= \mu_{3A} + RR1(\mu_{3B} - \mu_{3A}) \\ (M_+)_3 &= M_{3A} + RR1(M_{3B} - M_{3A}) \\ (R_+)_3 &= R_{3A} + RR1(R_{3B} - R_{3A}) . \end{aligned} \quad A-13$$

Also, the transmitted shock properties can be determined from the following equations:

$$(P_-)_3 = (P_+)_3 \left[ \frac{(M_+)_3^2 \sin^2 \omega_3 - \frac{\gamma-1}{2\gamma}}{\frac{\gamma+1}{2\gamma}} \right]$$

$$(R_-)_3 = (R_+)_3 \left[ \frac{\frac{\gamma+1}{\gamma-1} (M_+)_3^2 \sin^2 \omega_3}{(M_+)_3^2 \sin^2 \omega_3 + \frac{2}{\gamma-1}} \right]^{\frac{\gamma}{\gamma-1}}$$

$$\times \left\{ \frac{2\gamma}{\gamma+1} \left[ (M_+)_3^2 \sin^2 \omega_3 - \frac{\gamma-1}{2\gamma} \right] \right\}^{\frac{-1}{\gamma-1}}$$

$$(\theta_-)_3 = (\theta_+)_3 + \delta_3$$

$$\delta_3 = \tan \left[ \frac{(M_+)_3^2 \sin 2\omega_3 - 2 \cot \omega_3}{(M_+)_3^2 (\gamma + \cos 2\omega_3) + 2} \right] .$$

Before a new value for  $\omega_3$  is calculated, however, the currently calculated pressure  $(P_-)_3$  is compared with the previous value to determine if the solution had converged. For this

$$\left| (P_-)_3(i) - (P_-)_3(i+1) \right| < .001 (P_-)_3(i)$$

is considered satisfactory. To calculate Point 4, the Newton iteration procedure is used. Thus

$$f(RR2) = RR2 - \left( \frac{X_2 - X_1}{Y_2 - Y_1} \right) \left[ \frac{Y_3 - Y_1}{X_2 - X_1} + \left( RR2 + \frac{X_1 - X_3}{X_2 - X_1} \right) \right. \\ \left. \tan \left\{ \frac{1}{2} RR2 \left[ (\theta + \mu)_2 - (\theta + \mu)_1 \right] + \right. \right. \\ \left. \left. \frac{1}{2} \left[ (\theta + \mu)_1 + (\theta + \mu)_3 \right] \right\} \right]$$

where

$$RR2 = \frac{X_4 - X_1}{X_2 - X_1}$$

With RR2 calculated, properties at 4 are determined as

$$X_4 = X_1 + RR2 (X_2 - X_1)$$

$$Y_4 = Y_1 + RR2 (Y_2 - Y_1)$$

$$P_4 = P_1 + RR2 (P_2 - P_1)$$

$$\theta_4 = \theta_1 + RR2 (\theta_2 - \theta_1)$$

$$\mu_4 = \mu_1 + RR2 (\mu_2 - \mu_1)$$

so that a shock angle correction  $\Delta \omega$  can be calculated by

$$\Delta \omega = \frac{- \left[ \frac{P_3 - P_4}{\gamma P_{3,4}} + \frac{\theta_3 - \theta_4}{\cos \mu_{3,4} \sin \mu_{3,4}} \right]}{\frac{1}{\gamma P_{3,4}} \left( \frac{\partial P}{\partial \omega} \right)_3 + \frac{1}{\cos \mu_{3,4} \sin \mu_{3,4}} \left( \frac{\partial \theta}{\partial \omega} \right)}$$

where

$$\left( \frac{d\theta}{d\omega} \right) = (\gamma + 1) \sin^2 \delta_3 \frac{(M_+)_3^4 \sin^2 \omega_3}{[(M_+)_3^2 \sin^2 \omega_3 - 1]^2} - \frac{\sin 2 \delta_3}{\sin 2 \omega_3}$$

The new approximation to the shock angle, therefore, is determined by the equation

$$\omega_{3(i+1)} = \omega_{3(i)} + \Delta \omega$$

A-18

This iteration procedure continues until the pressure values in two successive iterations satisfy the criterion given above.

1. Assume a shock angle  $\omega_3$ . The initial approximation is taken as  $\omega_1$ .
2. Calculate  $RR1$  by iterating Eq. A12 until  $\left| RR1_{(i)} - RR1_{(i+1)} \right| \leq 10^{-5}$ .
3. Calculate the incident and transmitted shock properties at 3 and determine if  $\left| (P_-)_3(i) - (P_-)_3(i+1) \right| < .001 (P_-)_3(i)$ .
4. If the above condition is satisfied the solution is converged; otherwise, calculate  $RR2$  by iterating Eq. A15 until

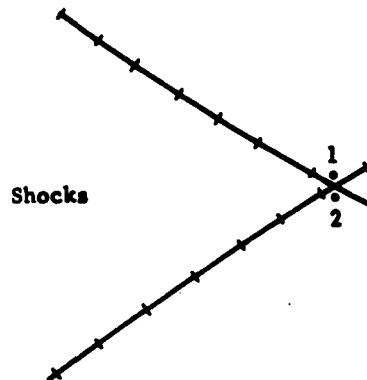
$$|RR2_{(i)} - RR2_{(i+1)}| < 10^{-5}.$$

- ### SPECIAL SHOCK-BODY, SHOCK-SLIPSTREAM CALCULATION

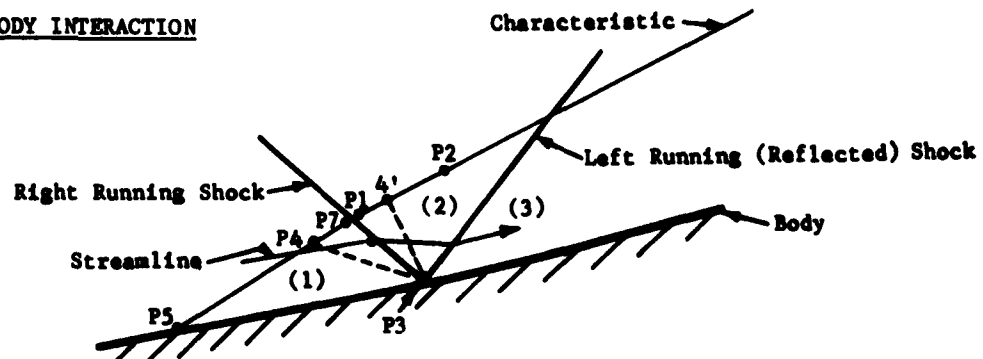
In these calculations, the data at Point 2 shown in the sketch of the previous section are not available. A body or slipstream Point 5 must be first determined by calculating a right running characteristic from Points 3 to 5 so that the values at Point 4 can be interpolated between Points 1 and 5. The body point and slipstream point calculation procedures are described in Appendix C.

#### INTERSECTION OF SHOCK OF THE OPPOSITE FAMILY

The location of the shock interaction of opposite family is calculated by a special curve fit procedure. This procedure utilizes the coordinate points of the two shocks to determine the location and the respective slopes at the point of shock interaction. From these slopes the shock wave angles and the incident flow properties, the transmitted shock properties ( $M$ -,  $P$ -,  $\delta$ , and  $R$ - at Points 1 and 2), can be directly calculated by the oblique shock relationships given in section A-1.

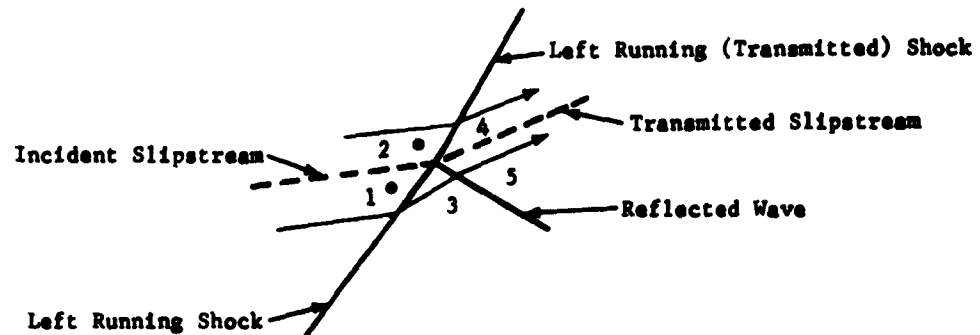


#### SHOCK-BODY INTERACTION



This routine calculates a shock point at the body surface  $P_3$  from Points  $P_7$  and  $P_1$  in the above sketch. Here, the flow properties in regions (1) and (2) are calculated in a manner similar to the field shock procedure and the flow properties at region (3) are calculated by the oblique shock procedure. The incident properties in region (1), however, must be determined by calculating a characteristic from  $P_4$  to  $P_3$  (right runner in the sketch). The shock strength between regions (2) and (3) must be adjusted so that the resulting flow in region (3) is parallel to the solid surface.

### SHOCK-SLIPSTREAM INTERACTION



This routine calculates the reflected wave, the transmitted shock, and the transmitted slipstream resulting from a shock-slipstream interaction. The location of the interaction point is first determined in a manner similar to that of the shock-shock interaction procedure described in Appendix A-4. The properties at Points 1 and 2 can be determined by interpolating the values along the incident slipstream which had been calculated beyond the point of interaction. Now, the procedure is to first assume a transmitted slipstream angle, and from this angle, the properties at Point 4 can be calculated by the oblique shock routine (Appendix A-1) and the properties at Point 3 can be calculated by the field shock routine (Appendix A-2). The reflected wave can be an expansion or compression type depending on the change in flow direction from Points 3 to 5. The flow angle at Point 5, of course, is the assumed transmitted slipstream angle. The properties at Point 5 are determined by the expansion routine (Appendix D) when the reflected wave is an expansion wave; when it is a compression wave, the oblique shock routine is used. The condition to be satisfied here is that the static pressure across the slipstream (Points 4 and 5) must be equal. It is seen that for each assumed transmitted slipstream angle two values of pressure ( $P_{41}$  and  $P_{51}$ ) are generally obtained. The procedure, therefore, is to iterate on the transmitted slipstream angle until the pressure at Points 4 and 5 are equal.

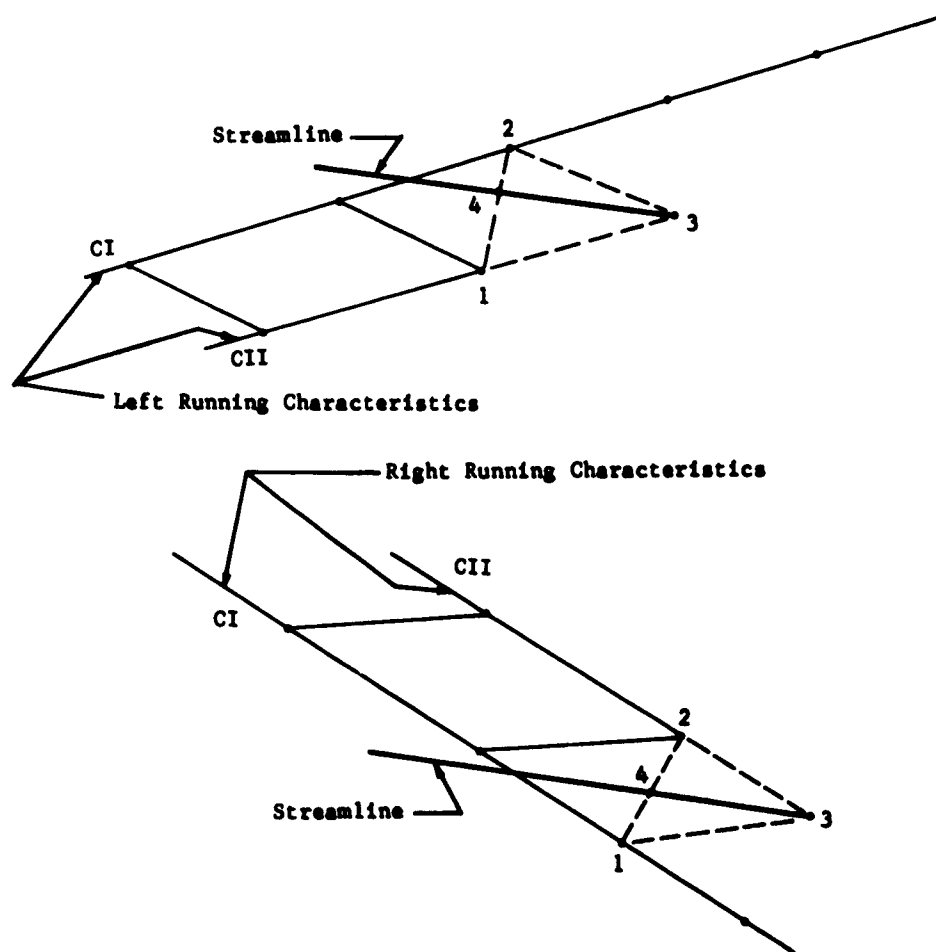
**APPENDIX B**  
**FIELD POINT CALCULATION**

## APPENDIX B

### FIELD POINT CALCULATION

Field points are points at which all flow properties are continuous. The method of calculation is to determine the point of intersection of two characteristics of opposite families passing through two known base points, and compute the flow properties at this new point through the use of the compatibility equations,

$$\frac{dp}{\gamma p} \pm \frac{d\theta}{\cos\mu \sin\mu} = 0$$



The above sketches show the two base Points (1 and 2) and the point to be determined (3). Point 4 is the intersection of the upstream portion of the streamline passing through Point 3 and a straight line connecting Points 1 and 2. Since the total pressure is constant along a streamline, the total pressure at Point 3 can be determined by interpolating between 1 and 2 to obtain the value at 4. The location of Point 3 is found by solving the equations of the characteristics passing through Points 1 and 2;

$$\gamma \quad Y_3 = \frac{\left[ X_2 - X_1 - \frac{Y_2}{\tan(\theta \pm \mu)_{2,3}} + \frac{Y_1}{\tan(\pm \mu)_{1,3}} \right]}{\left[ \frac{1}{\tan(\theta \pm \mu)_{1,3}} - \frac{1}{\tan(\theta \pm \mu)_{2,3}} \right]} \quad \text{B-1}$$

$$X_3 = X_1 + \frac{Y_3 - Y_1}{\tan(\theta \pm \mu)_{1,3}} \quad \text{B-2}$$

where the average values  $(2,3,1,3)$  are first assumed to be the values at Points 1 and 2. Now, the compatibility equations may be solved in their finite difference form for  $P_3$  and  $\theta_3$ .

$$P_3 = P_2 + \gamma \frac{P_2 + P_3}{2} \left[ \frac{\theta_3 - \theta_2}{\cos \mu_{2,3} \sin \mu_{2,3}} \right]$$

$$\theta_3 = \theta_2 + \frac{\frac{\frac{P_1 - P_2}{\gamma}}{\frac{P_1 + P_3}{2}} + \frac{\theta_1 - \theta_2}{\cos \mu_{1,3} \sin \mu_{1,3}}}{\frac{1}{\cos \mu_{1,3} \sin \mu_{1,3}} + \frac{\frac{P_2 + P_3}{2}}{\frac{P_1 + P_3}{2} \cos \mu_{2,3} \sin \mu_{2,3}}}$$

In order to compute  $\mu_3$ , the stagnation pressure ratio ( $R$ ) at Point 3, is needed, and is computed by first locating Point 4. Assuming  $R$  varies linearly between Points 1 and 2,  $R_3$  is determined by

$$R_3 = R_4 = R_2 + \frac{X_4 - X_2}{X_1 - X_2} (R_1 - R_2)$$

The only unknown in this equation is  $X_4$  which is calculated by

$$X_4 = X_2 + \Delta X$$

where

$$\Delta X = -D \pm \sqrt{D^2 - E}$$

$$D = \frac{1}{2} \left[ \frac{(X_1 - X_2)(\tan \theta_3 + \tan \theta_2)}{\tan \theta_1 - \tan \theta_2} + (X_2 - X_3) - \frac{2(Y_1 - Y_2)}{\tan \theta_1 - \tan \theta_2} \right]$$

B-3

$$E = \left( \frac{X_1 - X_2}{\tan \theta_1 - \tan \theta_2} \right) \left[ (X_2 - X_3)(\tan \theta_3 - \tan \theta_2) - 2(Y_2 - Y_3) \right]$$

These equations are derived from the following relations:

$$\frac{\tan \theta_4 - \tan \theta_2}{\tan \theta_1 - \tan \theta_2} = \frac{X_4 - X_2}{X_1 - X_2}$$

$$\frac{Y_4 - Y_3}{X_4 - X_3} = \frac{1}{2} (\tan \theta_4 - \tan \theta_3)$$

$$\frac{Y_1 - Y_2}{X_1 - X_2} = \frac{Y_4 - Y_2}{X_4 - X_2}$$

which assume a linear variation of the flow properties between Points 1 and 2. The root being used in equation B-3 is the one which makes  $\left| \frac{1}{2} - \frac{E}{X_1 - X_2} \right|$  a minimum.

Finally, the Mach angle at Point 3 (  $\mu_3$  ) is calculated from

$$\mu_3 = \tan^{-1} \left\{ \frac{2}{1-\gamma} \left[ 1 - \left( \frac{P_3}{P_2} \right)^{\frac{1-\gamma}{\gamma}} \right] \right\}^{\frac{1}{2}}$$

This completes one cycle of the calculation of Point 3. These new flow properties are used to determine new average values ( $\overline{1,3}$ ,  $\overline{2,3}$ ) which are substituted back into the geometric equations (B-1 and B-2) to recalculate a new location of Point 3. The calculation is repeated until

$$\left| P_{3(i)} - P_{3(i-1)} \right| \leq .001 P_{3(i)}$$

at which time the calculation of the field point is complete.

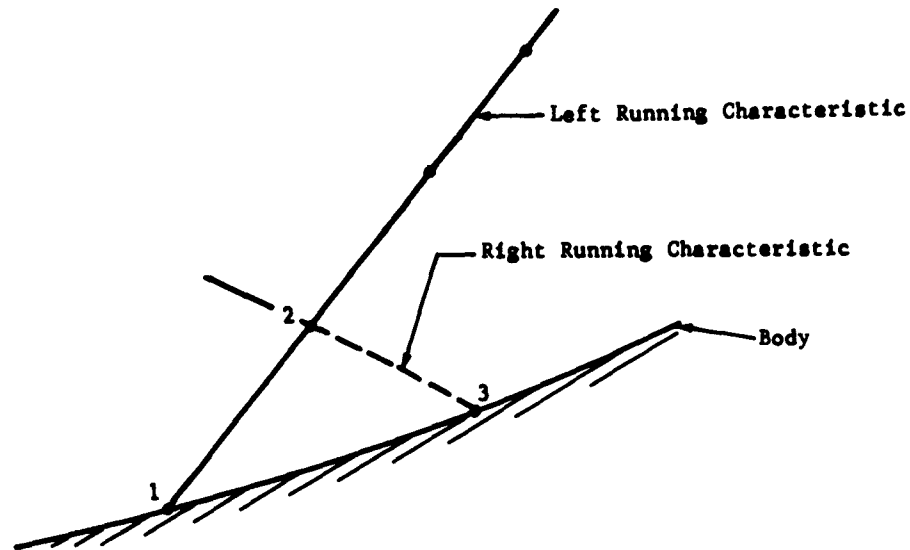
**APPENDIX C**  
**BOUNDARY POINT CALCULATION**

## APPENDIX C

### BOUNDARY POINT CALCULATION

Boundary points considered here are those being calculated along the solid surfaces and slipstreams.

#### SOLID BOUNDARY



In the above sketch, a body Point 3 is to be determined by calculating along a characteristic from 2. Since the total pressure is constant along a solid surface, the total pressure at 3 is obtained from the known value at 1.

The procedure is to first approximate the location of Point 3. The body curvature is defined locally by a cubic in the form

$$Y = AX^3 + BX^2 + CX + D, \quad \text{C-1}$$

and the characteristic equation between 2 and 3 is given as

$$\frac{Y_3 - Y_2}{X_3 - X_2} = \tan(\theta \pm \mu)_{2,3} \quad \text{C-2}$$

Combining, we have

$$f(X_3) = AX_3^3 + BX_3^2 + CX_3 + D - Y_3 - (X_3 - X_2) \tan(\theta \pm \mu)_{2,3} \quad \text{C-3}$$

from which  $X_3$  can be determined by a Newton iteration procedure. With  $X_3$  computed, the properties  $(\theta, P, \mu)$  at 3 can be determined directly by

$$\theta_3 = \tan^{-1}(Y_3) = \tan^{-1}(3AX_3^2 + 2BX_3 + C)$$

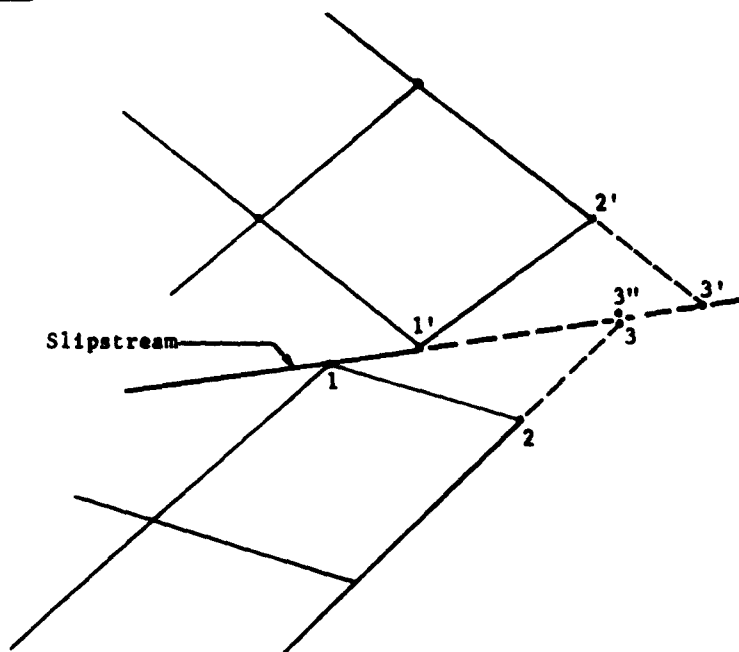
$$P_3 = P_2 + \gamma P_{2,3} \left[ \pm \frac{\theta_3 - \theta_2}{\cos(\mu)_{2,3} \sin(\mu)_{2,3}} \right]$$

$$\mu_3 = \tan^{-1} \sqrt{\frac{1}{\frac{2}{1-\gamma} \left[ 1 - \left( \frac{P_3}{R_3} \right)^{\frac{\gamma-1}{\gamma}} \right] - 1}}$$

With these properties determined, a new set of average properties  $(2, 3)$  can now be calculated, and hence, a new approximate location of  $X_3$  can be determined. The calculation is repeated until

$$|P_{3(i+1)} - P_{3(i)}| \leq .001 P_{3(i)}$$

#### SLIPSTREAM BOUNDARY



In the sketch on the previous page, Points 3 and 3' on the slipstream are to be calculated from Points 2 and 2' respectively. The procedure for calculating points on slipstream is similar to that for a solid surface except that here, the boundary location is not given and must be determined by matching the condition calculated from both sides of the slipstream. The conditions to be satisfied along a streamline are that the flow direction and static pressure must be equal.

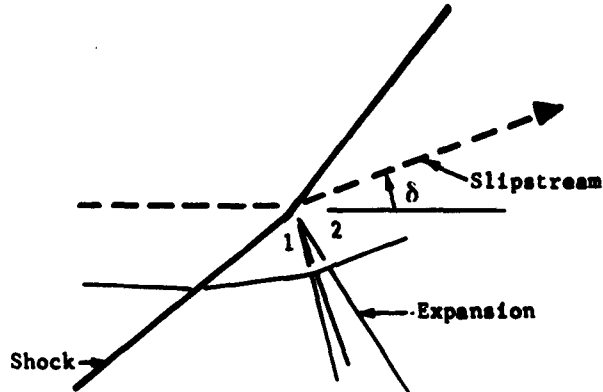
Each segment of the streamline is assumed to be a straight line. Thus, by assuming a slipstream direction (from Point 1 to Point 3') the properties at Points 3 and 3' can be calculated by a procedure similar to that of a solid boundary. In order to compare the pressure at the same location along the slipstream, however, a  $P_3''$  is interpolated between Points 1' and 3' which should be equal to  $P_3$ . In this way, by assuming a series of slipstream directions, a table of  $P_3$  and  $P_3''$  vs the slipstream angle can be established. The solution of the slipstream angle will be the value at which  $P_3 = P_3''$ . This value can be calculated by the special curve fit procedure (Subroutine MEET) which determines the intersection point of two given curves.

**APPENDIX D**  
**EXPANSION WAVE CALCULATION**

## APPENDIX D

### EXPANSION WAVE CALCULATION

The configuration considered in the present program is shown in the sketch below where a discontinuity in flow direction is caused by a shock slipstream interaction.



The calculation here is to determine the flow properties at 2 for a given flow deflection angle  $\delta$  which is equal to the increase in the Prandtl-Meyer angle  $\nu(M)$  from 1 to 2. The Prandtl-Meyer angle is defined as

$$\nu(M) = \sqrt{\frac{\gamma+1}{\gamma-1}} \tan^{-1} \sqrt{\frac{\gamma-1}{\gamma+1} (M^2-1)} - \tan^{-1} \sqrt{M^2-1} \quad D-1$$

From a known Mach number at 1 ( $M_1$ ),  $\nu_1 (M_1)$  can be directly calculated. To determine  $M_2$  for a given deflection angle, however, an iteration must be carried out. The flow deflection  $\delta$ , is related to the Prandtl-Meyer angle by

$$\delta = \nu_2(M_2) - \nu_1(M_1) \quad D-2$$

The method of calculation is to first establish a table of  $M$  vs  $\nu$  (Eq. D-1) and by interpolating this table,  $M_2$  can be determined directly from a  $\nu_2$  calculated by Eq. D-2. Thus, from  $M_2$ , the properties at 2 can be calculated from

$$P_2 = P_1 \left( 1 + \frac{\gamma-1}{2} M_2^2 \right)^{-\frac{\gamma}{\gamma-1}}$$

$$\mu_2 = \tan^{-1} \left( \frac{1}{\sqrt{M_2^2-1}} \right)$$

where  $R_2 = R_1$ , since the flow expansion from 1 to 2 is isentropic.

**APPENDIX E**  
**AUXILIARY SUBROUTINES**

## APPENDIX E

### AUXILIARY SUBROUTINES

#### SUBROUTINES CURFIT \*

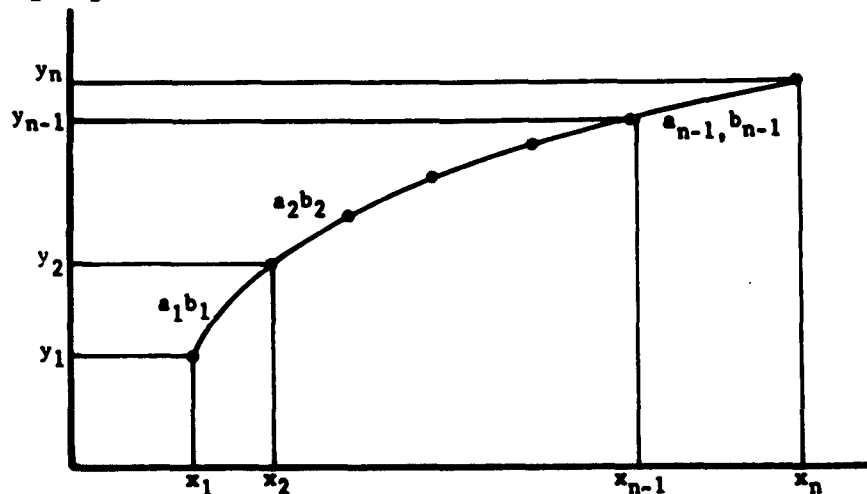
Subroutine CURFIT computes the coefficients of the curve-fit function

$$y = f_1(x)$$

for a given table of y vs x such that the first and second derivatives  $[f_1'(x), f_1''(x)]$  are continuous within the range of the given table. The function  $f_1(x)$  is defined as

$$y = y_1 + \frac{y_{i+1} - y_1}{x_{i+1} - x_1} (x - x_1) + a_1 (x - x_1)(x_{i+1} - x) + b_1 (x - x_1)^2 (x_{i+1} - x) \quad E-1$$

which is a cubic expression defined by the points at i and i+1, and the two coefficients  $(a_1, b_1)$  for each of the given *i*th intervals (see sketch below).



The coefficients  $a_1$  and  $b_1$  are determined by setting the first and second derivatives of the interpolation formulae for the *i*th and (*i*+1)th intervals equal at  $x = x_{i+1}$ . That is

$$\left( \frac{dy}{dx} \right)_i \bigg|_{x=x_{i+1}} = \left( \frac{dy}{dx} \right)_{i+1} \bigg|_{x=x_{i+1}} \quad E-2$$

\* This routine is an extension of the SHARE subroutine E2-GEFCDIS.

$$\left( \frac{d^2 y}{dx^2} \right)_i \bigg|_{x=x_{i+1}} = \left( \frac{d^2 y}{dx^2} \right)_{i+1} \bigg|_{x=x_{i+1}} \quad \text{E-3}$$

Substitute Eq. E-1 into E-2 and E-3 respectively; one obtains

$$\begin{aligned} \left[ \frac{(x_{i+1}-x_i)}{(x_{i+2}-x_{i+1})} \right] a_i + \left[ \frac{(x_{i+1}-x_i)^2}{(x_{i+2}-x_{i+1})} \right] b_i + a_{i+1} \\ = \frac{(y_{i+1}-y_i)}{(x_{i+1}-x_i)(x_{i+2}-x_{i+1})} - \frac{(y_{i+2}-y_{i+1})}{(x_{i+2}-x_{i+1})^2} \end{aligned} \quad \text{E-4}$$

$$\begin{aligned} \frac{(x_{i+1}-x_i)}{(x_{i+2}-x_{i+1})} b_i - \frac{(x_{i+2}-x_i)}{(x_{i+1}-x_i)(x_{i+2}-x_{i+1})} a_{i+1} + b_{i+1} \\ = \frac{(y_{i+2}-y_{i+1})}{(x_{i+1}-x_i)(x_{i+2}-x_{i+1})^2} - \frac{(y_{i+1}-y_i)}{(x_{i+1}-x_i)^2(x_{i+2}-x_{i+1})} \end{aligned} \quad \text{E-5}$$

Equations E-4 and E-5 apply for the  $i+2$ ,  $n-2$  intervals, and hence, represent a system of  $2n-4$  equations in  $2n-2$  unknowns. Two additional equations, therefore, are needed, and they can be obtained by specifying either the first or second derivatives at both ends of the table. These equations are

$$\left( \frac{dy}{dx} \right)_{x=x_1} = \frac{y_2 - y_1}{x_2 - x_1} + a_1 (x_2 - x_1) \quad \text{E-6}$$

$$\left( \frac{d^2 y}{dx^2} \right)_{x=x_1} = -2a_1 + 2b_1(x_2 - x_1)$$

$$\begin{aligned} \left( \frac{dy}{dx} \right)_{x=x_n} &= \frac{y_n - y_{n-1}}{x_n - x_{n-1}} - a_{n-1} (x_n - x_{n-1}) \\ &\quad - b_{n-1} (x_n - x_{n-1})^2 \end{aligned} \quad \text{E-7}$$

$$\left( \frac{d^2 y}{dx^2} \right)_{x=x_n} = -2a_{n-1} + 4b_{n-1} (x_n - x_{n-1})$$

Equations E-4, E-5, E-6 and E-7 represent a tri-diagonal matrix system of the simultaneous linear equations in  $a_i$  and  $b_i$ . Hence, the solution  $(a_i, b_i)$  can be obtained by a special matrix inversion procedure which is done in CURFIT.

#### SUBROUTINE CURVE

Subroutine CURVE utilizes the curve fit coefficient computed in subroutine CURFIT to calculate the quantities  $y(x)$  and  $y'(x)$  for a given  $x$ . The subroutine will also perform straight line extrapolations beyond both ends of the table.

#### SUBROUTINE CUBIC

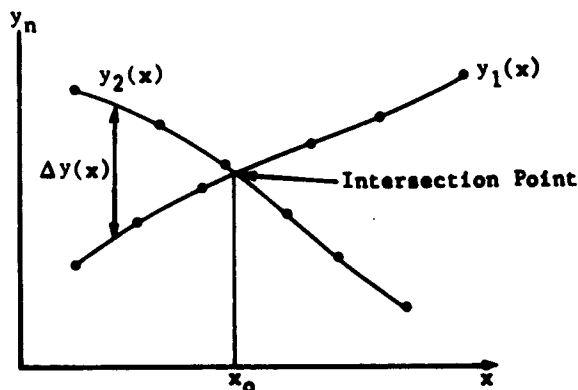
Subroutine CUBIC recalculates coefficients computed by subroutine CURFIT to those corresponding to equations of the form

$$y(x) = Ax^3 + Bx^2 + Cx + D$$

A combination of straight lines and cubic curves can be also fitted smoothly within a given table.

#### SUBROUTINE MEET

Subroutine MEET determines the intersection point of two given curves which are specified as two independent tables  $y_1(x)$  and  $y_2(x)$



By using subroutine CURFIT, a table of  $x$  vs  $\Delta y(x)$  can be first established, where

$$\Delta y(x) = y_2(x) - y_1(x)$$

This table can then be curve fitted to obtain  $x_0$  of the intersection point where  $\Delta y = 0$ . With  $x_0$  determined, therefore, the  $y$  and the derivatives  $y'_1(x_0)$  and  $y'_2(x_0)$  at the intersection point can be again determined by subroutine CURFIT.

**APPENDIX F**  
**DESCRIPTION OF DATA INPUT**  
**AND OUTPUT**

## APPENDIX F

### DESCRIPTION OF DATA INPUT AND OUTPUT

#### INPUT

This program requires the following input data:

- (1) A title or job description card.
- (2) Blade type indicator (sharp or blunt leading edges).
- (3)  $M_\infty$  - free stream Mach number.
- (4)  $P_\infty$  - free stream pressure (atmospheres).
- (5)  $T_\infty$  - free stream temperature ( $^{\circ}\text{K}$ ).
- (6)  $\gamma$  - specific heat ratio.
- (7) Channel geometry - in numerical form. Two X vs Y tables must be provided, one for the upper (expansion) surface and the other for the lower (compression) surface. For blunt leading edge cases, the leading edge radii, the location of the radius centers, and the tangent point angles ( $\theta_U$  and  $\theta_L$ , in degrees) are also required. The formats and the ordering of the data are described in Table F-1.

In preparing the input data, the following assumptions and rules should be observed:

- 1)  $N_U, N_L$  cannot be greater than 20 for a sharp leading edge case and cannot be greater than 18 for a blunt leading edge case.
- 2)  $R_L = R_U$ .
- 3)  $\theta_L, \theta_U > 65^{\circ}$ .
- 4) To be compatible with the present boundary layer program,  $\gamma$  should be set equal to 1.4.
- 5) For a sharp leading edge case, straight lines are fitted for the first and the last segments in the two X vs Y tables (between Points 1 and 2 and between Points N-1 and N). If the surfaces are curvilinear in those regions, these points should be closely tabulated so that the straight line approximation is valid.
- 6) For a blunt leading edge case, the first tabulated point on each surface is the tangent point, and the first interval should be greater than one leading edge radius. This is required to fit a smooth curve in that region. A key punch form and two examples of data input are included in the following:

TABLE F1  
INPUT DATA AND FORMAT

FORMAT*	DATA	DESCRIPTION	No. of CARDS
(10A6)	Title or Job Description Card	Maximum of 60 alphanumeric characters col. 1-60).	1
(11, 9X, 4F10.6)	IND, $M_{\infty}$ , $P_{\infty}$ , $T_{\infty}$ ,	IND = 1 for sharp leading edge IND = 2 for blunt leading edge	1
(15, 4F10.6/ (6F10.6))	$N_U$ , $R_U$ , $\theta_U$ , $X_{CU}$ , $Y_{CU}$ , ( $X_U(I)$ , $Y_U(I)$ , $I = 1, N_U$ )	Upper surface geometry Symbols are defined in Figures F1 & F2. For sharp leading-edge case, $R_U$ , $\theta_U$ , $X_{CU}$ , $Y_{CU}$ data are not required.	1 + 1 per 3 points .
(15, 4F10.6/ (6F10.6))	$N_L$ , $R_L$ , $\theta_L$ , $X_{CL}$ , $Y_{CL}$ , ( $X_L(I)$ , $Y_L(I)$ , $I = 1, N_L$ )	Lower surface geometry. Symbols are defined in Figures F1 & F2. For sharp leading edge case, $R_L$ , $\theta_L$ , $X_{CL}$ , $Y_{CL}$ data are not required.	1 + 1 per 3 points
* In FORTRAN II Language			

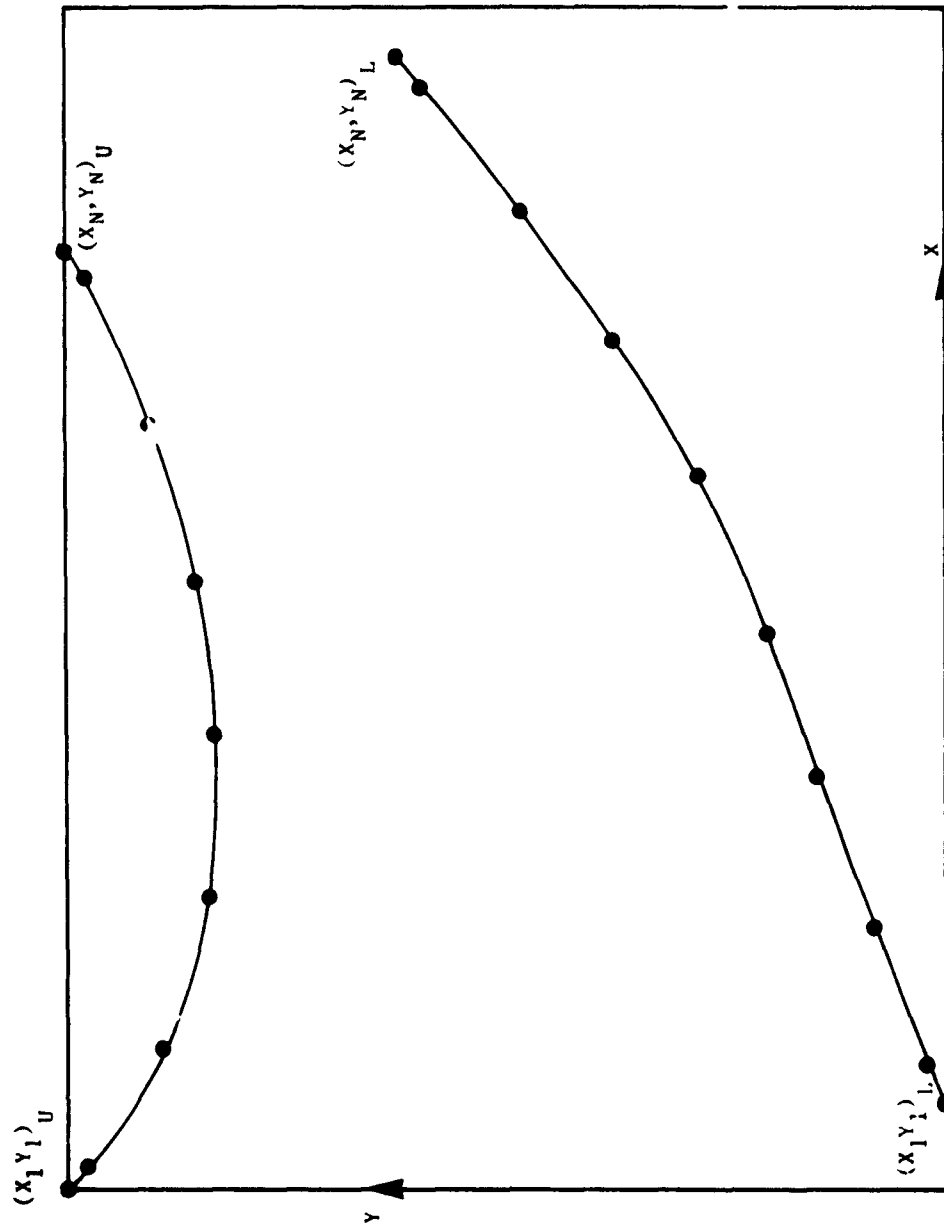


FIGURE F1 SHARP LEADING-EDGE CHANNEL GEOMETRY INPUT

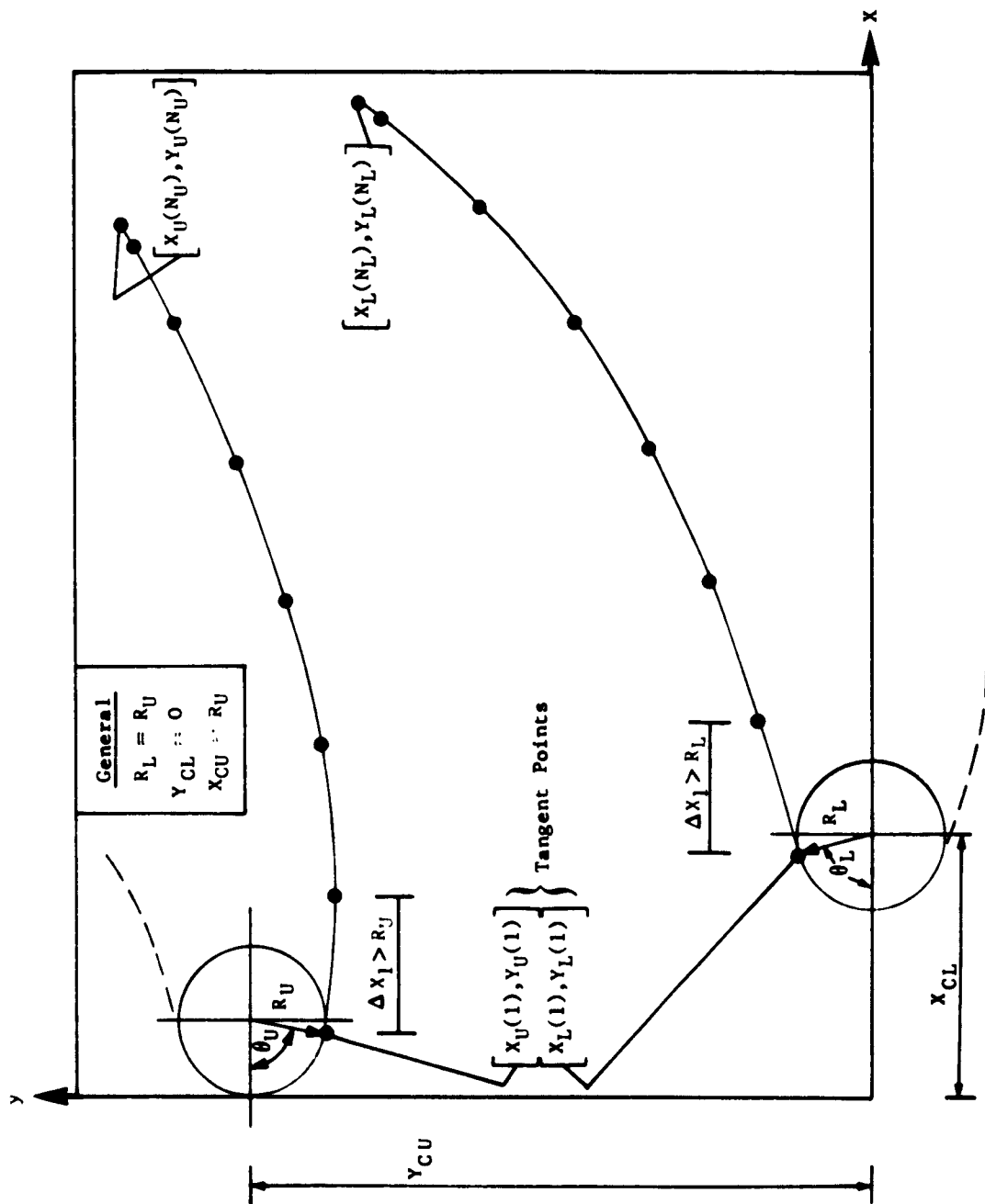


FIGURE F2 BLUNT LEADING-EDGE CHANNEL GEOMETRY INPUT

# KEY PUNCH FORM - GENERAL PURPOSE

Form 20-700 (2-1-60)

JOB TITLE										ENGINEER										PAGE																																																	
SUS										EDU NO.										FOR ORGN. NO.										ANALYST										DATE										OF																			
TURNING VANE INPUT DATA																																																																					
TITLE CARD (ALPHANUMERIC COLS. 1 - 60)																																																																					
M <sub>0</sub>										P <sub>0</sub>										T <sub>0</sub>										Y																																							
N <sub>U</sub>										R <sub>U</sub>										β <sub>U</sub> °										X <sub>CU</sub>										Y <sub>CU</sub>																													
X <sub>U1</sub>										Y <sub>U1</sub>										X <sub>U2</sub>										Y <sub>U2</sub>										X <sub>U3</sub>										Y <sub>U3</sub>																			
X <sub>NU-2</sub>										Y <sub>NU-2</sub>										X <sub>NU-1</sub>										Y <sub>NU-1</sub>										X <sub>NU</sub>										Y <sub>NU</sub>																			
N <sub>L</sub>										R <sub>L</sub>										β <sub>L</sub> °										X <sub>CL</sub>										Y <sub>CL</sub>																													
X <sub>L1</sub>										Y <sub>L1</sub>										X <sub>L2</sub>										Y <sub>L2</sub>										X <sub>L3</sub>										Y <sub>L3</sub>																			
X <sub>NL-2</sub>										Y <sub>NL-2</sub>										X <sub>NL-1</sub>										Y <sub>NL-1</sub>										X <sub>NL</sub>										Y <sub>NL</sub>																			

## Form 20-702 (R. 1-60)

77

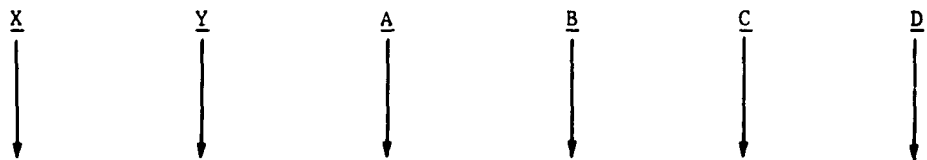
## Form 26-709 (R. 1-60)

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## OUTPUT

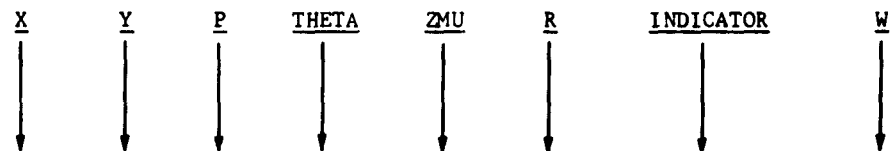
### I INVISCID PROGRAM

- (1) Job title
- (2)  $M_{\infty}$   
 $P_{\infty}$  (atm)  
 $T_{\infty}$  ( $^{\circ}$ K)
- (3) Body Description



where (X, Y) - input points  
(A, B, C, D) - coefficients of cubics

- (4) Characteristic Output (along a characteristic)



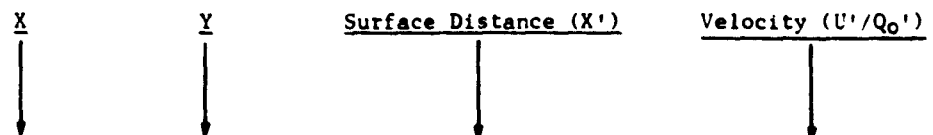
P -  $P/P_{t\infty}$   
THETA - Flow Direction (radians)  
ZMU - Mach Angle (radians)  
R -  $P_t/P_{t\infty}$   
Indicator - defines point type - shock, body, vortex, or field  
(field points are denoted by \*\*\*)  
W - shock angle (radians)

### II BOUNDARY DATA FOR BOUNDARY LAYER CALCULATION

- (1) Boundary Layer Input Data - Upper surface

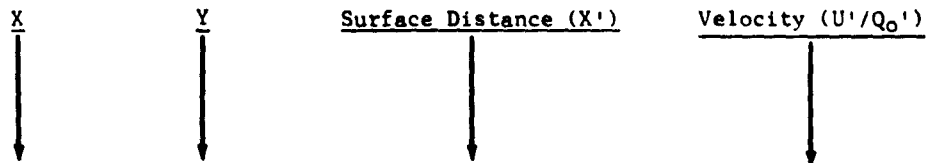
$T2T1$  = temperature ratio  
 $P2P1$  = pressure ratio  
 $U2U1$  = velocity ratio  
 $P3P2$  = pressure ratio across shock body interaction point,

} across the primary shock  
at leading edge



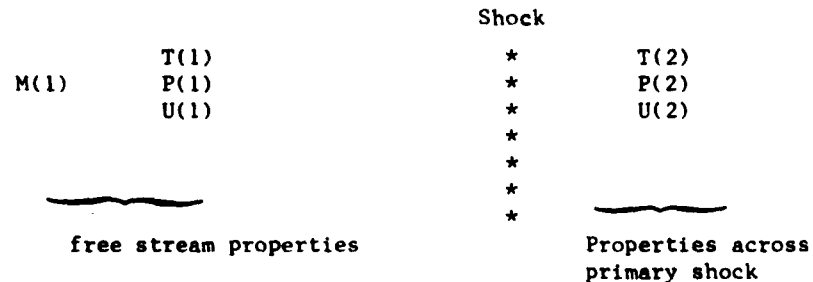
(2) Boundary Layer Input Data - Lower surface

$T2T1$  = temperature ratio } across primary shock  
 $P2P1$  = pressure ratio } at leading edge  
 $U2U1$  = velocity ratio }  
 $P3P2$  = pressure ratio across shock body interaction point



III BOUNDARY LAYER PROGRAM

(1)



where

T - temperature (°K)  
 P - pressure (atm)  
 U - velocity (ft/sec)

(2) RE/FT - Reynolds number per ft.

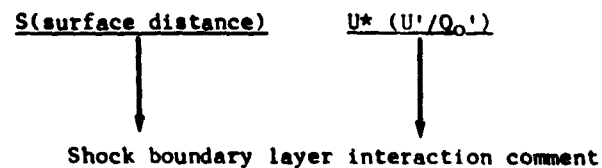
(3)  $L(0) - L_0'$

SOLAR HEAT (set to zero)

EMISSION OF SURFACE (set to zero)

DEL 1, DEL 2 (Surface distance over which pressure jump is being spread fore and aft of a shock boundary layer interaction point)

(4) INVISCID DATA



(5) FIX DATA

S (ξ<sup>2</sup>)



U\* (U'/Q<sub>0</sub>)



(6)

I, J, V, T

where

I, J - integration step counter in the longitudinal and transverse directions

V - inviscid transverse velocity component

T - non-dimensional temperature

A - coefficients

XI-SQ(ξ<sup>2</sup>)

CP (C<sub>p</sub>) - pressure coefficient =  $\frac{P - P_{\infty}}{\frac{\gamma}{2} P_{\infty} M_{\infty}^2}$

} defined in List of Symbols  
(Boundary Layer Equations)

U\* (U'/Q<sub>0</sub>) - velocity ratio

T\* - inviscid temperature (°K)

F(0)\* - suction velocity (set to zero)

(7) I, J - defined in (6)

K



V



T



PHI



MU



S



N



Z



K - vertical step counter

V - transverse velocity component (v)

T - non-dimensional temperature (τ)

PHI - non-dimensional shear parameters (φ)

MU - non-dimensional viscosity (μ)

S - longitudinal velocity component (parallel to Q)

N - transverse velocity component (perpendicular to Q)

Z - vertical distance

} defined in List of Symbols  
(Boundary Layer Equations)

DELS = δ\* (displacement thickness)

DELSS = δ\*\* (momentum thickness)

APPENDIX G  
FORTRAN PROGRAM LISTING

```

C
C
      TURNING VANE PROGRAM
      DIMENSION IND(100),X(100),Y(100)
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),
1      XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)
      DIMENSION AC1(6,20),AC2(6,20)
      DIMENSION ARRAY(12)
C
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2
      COMMON GAMMA,FSM,FSP,FST,SW
C
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(
15),ZMU1),
2 (XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),
3 (XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),
4 (XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),
5 (XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),
6 (XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),
7 (XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),
1 ZMU3A)
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),
1 (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),
2 (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),
3 (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),
4 (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),
5 (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),
8 (XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),
1 ZMU3B),
9 (XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),
6 (XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),

```

```

C
1 (XX3(10),NPONT3),(XX5(10),NPONT5)
400 FORMAT (6F10.6)
401 FORMAT (10I1,5F10.6)
402 FORMAT (48X10HINPUT DATA///10X20HFREE STREAM MACH NO.,
1 1PE15.5/10X20HFREE STREAM PRESSURE,1PE15.5/10X,
2 23HFREE STREAM TEMPERATURE,1PE15.5///)
410 FORMAT (44X,16HBODY DESCRIPTION//10X1HX,16X1HY,33X1HA,
4 16X1HB,16X1HC,16X1HD//)
403 FORMAT (12A6)
404 FORMAT (15,2E10.5)
409 FORMAT (1P2E17,7/52X,1P4E17.7)
READ INPUT TAPE 5,403,(ARRAY(I),I=1,12)
CALL PAGE2 (-1,ARRAY)
C
READ INPUT TAPE 5,401,(M(I),I=1,10),FSM,FSP,FST,GAMMA
WRITE OUTPUT TAPE 6,402,FSM,FSP,FST
REWIND 2
WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY
IF (M(1)-2) 50,888,50
CALL CHAIN (7,8)
888
C
50 CONTINUE
WRITE OUTPUT TAPE 6,410
READ INPUT TAPE 5,404,N1,S1,S2
READ INPUT TAPE 5,400,(X(I),Y(I),I=1,N1)
DO 10 I=1,20
IND(I) = 0
IND(1) = 1
IND(N1-1) = 1
CALL CUBIC (X,Y,IND,N1,S1,S2,AC1)
NN = N1
N = 0
C
70 DO 100 I=2,NN
C
IF (N) 80,80,90
80 WRITE OUTPUT TAPE 6,409,X(I-1),Y(I-1),AC1(2,I-1),AC1(3,I-1),
AC1(4,I-1),AC1(5,I-1)
GO TO 100
C
950J1031
950J1032
950J1033
950J1034
950J1035
950J1036
950J1037
950J1038
950J1039
950J1040
950J1041
950J1042
950J1043
950J1044
950J1045
950J1046
950J1047
950J1048
950J1049
950J1050
950J1051
950J1052
950J1053
950J1054
950J1055
950J1056
950J
950J
950J1057
950J1058
950J1059
950J1060
950J1061
950J1062
950J1063
950J1064
950J1065
950J1066
950J1067

```

```

90      WRITE OUTPUT TAPE 6,409,X(I-1),Y(I-1),AC2(2,I-1),AC2(3,I-
C      11), AC2(4,I-1),AC2(5,I-1)
100      CONTINUE
      IF (N) 110,110,120
110      N = 1
      WRITE OUTPUT TAPE 6,409,X(N1),Y(N1)
      READ INPUT TAPE 5,404,N2,S1,S2
      NN = N2
      READ INPUT TAPE 5,400,(X(I),Y(I),I=1,N2)
      DO 20 I=1,20
20      IND(I) = 0
      IND(1) = 1
      IND(N2-1) = 1
      CALL CUBIC (X,Y,IND,N2,S1,S2,AC2)
      GO TO 70
120     WRITE OUTPUT TAPE 6,409,X(N2),Y(N2)
      N1 = N1-1
      N2 = N2-1
      WRITE TAPE 2,AC1,AC2,N1,N2
      CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM,DUM)
C
C      TEST TYPE BODY.
C
      IF (M(1)-1) 999,130,999
C
130     CALL PAGE2 (0,ARRAY)
      CALL WEDGE
      CALL CHAIN (2,8)
C
999     CALLDUMP
      END

```

```

950J1068
950J1069
950J1070
950J1071
950J1072
950J1073
950J1074
950J1075
950J1076

950J
950J

950J1078
950J1079
950J1080
950J1081
950J1082
950J1083
950J1084
950J1085
950J1086
950J1087
950J1088
950J1089
950J1090
950J1091
950J1092
950J1093
950J1094

```

```

SUBROUTINE WEDGE
* LABEL
950JA
C
DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),
1 XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)
DIMENSION AC1(6,20),AC2(6,20)
C
COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2
COMMON GAMMA,FSM,FSP,FST,SW
C
EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(
15),ZMU1),
2 (XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),
3 (XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),
4 (XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),
5 (XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),
6 (XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),
7 (XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),
1 ZMU3A),
EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),
1 (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),
2 (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),
3 (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),
4 (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),
5 (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),
8 (XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),
1 ZMU3B),
9 (XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),
6 (XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)
C
EQUIVALENCE (XX3(7),NPT3),(XX1(7),NPT1),(NPT5,XX5(7))
EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),
1 (XX3(10),NPONT3),(XX5(10),NPONT5)
100 FORMAT (1P6E15.5)
REWIND 3
REWIND 4
C
CALCULATION ON UPPER BODY
C
C
C

```

```

X1 = AC1(1,1)
Y1 = ((AC1(2,1))*X1+AC1(3,1))*X1+AC1(4,1)
1 *X1+AC1(5,1)
TH1 = 0.0
R1 = 1.0
STH = ATANF((3.*AC1(2,1)*X1+2.*AC1(3,1))*X1+AC1(4,1))
FSMS = FSM**2
P1 = (1.+(GAMMA-1.)/2.*FSMS)**(-GAMMA/(GAMMA-1.))
ZMU1 = ATANF(SQRTF(1./(FSMS-1.)))
W1 = ZMU1
ZZMU = ZMU1
PP1 = P1
CALL SHK1 (-1.0,STH,XX1,XX3,GAMMA,M1)
IF (M1-1) 999,20,999
NPT3 = -2
NPT1 = -1
CALL DMOVE (W,XX3)
NPT1 = 12345
CALL DMOVE (W(1,2),XX1)
CALL STORE (B,W,3,M,ARRAY)

20 CALL SHOCK (1,M1,-1.0,XXA,XXB,XX1,XX3,XX2,XX3U,XX3,XX5,
1 GAMMA,10,FSM)
IF (M1-1) 999,10,999
NPT3 = 2
NPT5 = -2

C XX3(8) = -XX3(8)
CALL DMOVE (W,XX3)
CALL DMOVE (W(1,2),XX5)
NPT1 = 12345
CALL DMOVE (W(1,3),XX1)
CALL STORE (B,W,3,M,ARRAY)

C CALCULATION ON LOWER BODY
C
C X1 = AC2(1,1)
Y1 = ((AC2(2,1))*X1+AC2(3,1))*X1+AC2(4,1)*X1+AC2(5,1)
TH1 = 0.0
R1 = 1.0
STH = ATANF((3.*AC2(2,1)*X1+2.*AC2(3,1))*X1+AC2(4,1))

```

```

      W1 = ZZMU
      P1 = PPI
      ZMU1 = ZZMU

      ZMU1 = ATANF(SQRTF(1./((FSMS-1.)))
      CALL SHK1 (1.0,STH,XX1,XX3,GAMMA,M1)
      IF (M1-1) 999,30,999
      NPT3 = -1
      CALL DMOVE (W,XX3)
      NPT1 = 12345
      CALL DMOVE (W(1,2),XX1)
      CALL STORE (B,W,4,M,ARRAY)

      NPT3 = 1
      NPT5 = -1
      CALL SHOCK (1,M1,1.,XXA,XXB,XX1,XX3,XX2,XX3U,XX3,XX5,GAMMA,.1,
      1  FSM)
      IF (M1-1) 999,50,999
      CALL DMOVE (W,XX3)

      CALL DMOVE (W(1,2),XX5)
      NPT1 = 12345
      CALL DMOVE (W(1,3),XX1)
      CALL STORE (B,W,4,M,ARRAY)
      RETURN
      CALL EXIT
      END

```

950JA079  
 950JA080  
 950JA081  
 950JA082  
 950JA083  
 950JA084  
 950JA085  
 950JA086  
 950JA087  
 950JA088  
 950JA089  
 950JA090  
 950JA091  
 950JA092  
 950JA093  
 950JA094  
 950JA095  
 950JA096  
 950JA097  
 950JA098  
 950JA099  
 950JA100  
 950JA101  
 950JA102  
 950JA103  
 950JA104

```

C      MAIN PROGRAM CHAIN VII - TURNING VANE.
C      BELOTSERKOVSKIIS METHOD, SECOND APPROXIMATION
C      * LABEL
C      950J7
C
      DIMENSION V(7),DER(7),EK(4),ER(7),XN0(750),DN0(750),XN2(750),
      1DN2(750),ZNMS(50),EP(50),VR(50),CFT(4),VB4(50),VB7(50),CF4(4),
      2CF7(4)
      DIMENSION GAMMA(13)
C
      COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5,
      1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,
      2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,
      3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,
      4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7,NPT
C
      FORMAT(1H1)
      FORMAT(1H0)
      FORMAT(3X,1P7E16.7)
      FORMAT(1H0,4X,6HU2U1=1P1E15.7,5X,5H1R=13,5X,5HKR=13)
      FORMAT(1H0,4X,14HEPSILON ZERO=1P1E15.7)
      FORMAT(1H1,4X,38HUNABLE TO CONVERGE BLUNT BODY SOLUTION)
C
      EK(1)=0.5
      EK(2)=1.0-SQRTF(0.5)
      EK(3)=2.0-EK(2)
      EK(4)=0.33333333
C
      REWIND 2
      READ TAPE 2,C1,FSM
      X0 = 1.0
      A=1.0
      TMN=1.10
      CTF=1.0E-04
      DTH=0.02
      THT=2.2*DTH
      DEL=0.15
      EPS0=0.386*EXP(5.16/(FSM**1.96))
      U2U1=(0.665/FSM-0.042)/FSM+0.530
      NIN=6

```

```

NOPT=5
NDIM=0
M5=0
N1=NIN+1
NS2=1
C
C2=1.0/(C1-1.0)
C3=1.0/(C1+1.0)
C4=C3/C2
C5=C2/C3
C6=2.0*C3
C8=0.5/C2
C7=C8/C1
C9=C6/C7
C10=SQRTF(C4)
C11=2.0*C7
C12=C9*C4*C1
C13=C8**2/C1
FSMS=FSM**2
FSWS=1.0/(1.0/(C8*FSMS)+1.0)
FSW=SQRTF(FSWS)
FS1=1.0-FSWS
RORT=FS1**C2
FS2=FSWS*RORT
FS3=FSW*RORT
FS3=FSWS/FS1
FS4=((FSMS-1.0)**2)*(1.0-C1)/(FSW*(FSMS-C7)*FS1**C2-1.0))
PRAT=RORT*C1
PHI0=C12*(FS3-C13)/(FSWS**C1)
FENT=1.0/(PHI0**C2)
TERM=C6*(1.0-1.0/FSMS)
U1=-FSW*(1.0-TERM)
UONE=U1
UIS=U1**2
XN1=FSW*TERM
TAU1=(1.0-UIS)**C2
Q1=TAU1*U1
Q2=TAU1*XN1
Q3=TAU1*(C7*(1.0-UIS)+UIS)
Q4=Q1*XN1
C

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950J7038
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950J7078

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60	GO TO(60,61,64,62,63),NOPT	950J7079
	CT1=X0/A-1.0	950J7080
	CT2=CT1**2-1.0	950J7081
	CT3=1.0-(A/R)**2	950J7082
61	GO TO 64	950J7083
	CT1=X0/A	950J7084
	CT2=CT1-1.0	950J7085
62	GO TO 64	950J7086
	CT1=1.0+X0/A	950J7087
	CT2=CT1**2-1.0	950J7088
	CT3=1.0+(A/B)**2	950J7089
63	GO TO 64	950J7090
	RB=A	950J7091
	ETA=0.0	950J7092
	ETAP=0.0	950J7093
C 64	U20=U2U1*U1	950J7094
	NS1=1	950J7095
	NS3 = 1	950J7096
	KTR=1	950J7097
	EPSLB=-1000.0	950J7098
	EPSUB=-500.0	950J7099
98	U2N=500.0	950J7100
	U2P=1000.0	950J7101
	ESP=-1000.0	950J7102
	ESN=1000.0	950J7103
	IPT=0	950J7104
	ITR=0	950J7105
C		950J7106
100	IF(ITR-35) 101,50,50	950J7107
101	M2=1	950J7108
	ITR=ITR+1	950J7109
	JPT=0	950J7110
	M6=1	950J7111
102	IF(NDIM) 102,102,103	950J7112
	CALL NASTY	950J7113
	GO TO 104	950J7114
103	CALL MESSY	950J7115
104	E0=C4*DER(4)	950J7116
	DEN0=C4	950J7117
	DEN2=C4*(1.0-U20**2)	950J7118
		950J7119

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70 F2=DEN2*DER(7)
79 IF (NS3-2) 79,70,70
    CALL POOH(1)
    URA=U20/UONE
C
82 DO 90 I=1,7
90 ER(I)=0.0
105 DO 125 I=1,4
    IF(I-1) 107,107,106
106 M3=1
    IF(NDIM) 1061,1061,1062
1061 CALL NASTY
    GO TO 107
1062 CALL MESSY
107 IF(I-4) 115,110,110
110 EEK1=0.5
    EEK2=0.5
    GO TO 120
115 EEK1=1.0
    EEK2=EEK(1)
120 DO 125 J=1,7
    QER=EK(I)*(EEK1*DER(J)-ER(J))
    V(J)=V(J)+QER*DTH
125 ER(J)=ER(J)+3.0*QER-EEK2*DER(J)
C
M3=2
IF(NDIM) 126,126,127
126 CALL NASTY
    GO TO 128
127 CALL MESSY
128 IF (NS3-2) 145,135,135
135 CALL POOH(2)
C
145 IF(NS1-2) 150,320,610
150 W0=V(4)*SQRTF(1.0+ETA**2)
    IF(W0-(1.0-DEL)*C10) 152,157,157
152 IF(E0) 153,153,156
153 U2N=U20
    IF(U2P) 155,154,154
154 IF(KTR-2) 1400,1400,1410
1400 U20=(1.0+1.0E-02)*U20

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950J7120
950J7121
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950J7158
950J7159
950J7160

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1410 GO TO 100
      U20=(1.0+1.0E-07)*U20
1411 GO TO 100
155  U20=0.5*(U2P+U2N)
      GO TO 180
156  JPT=JPT+1
      IF(JPT-750) 190,190,50
190  DNO(JPT)=DENO
      XN0(JPT)=E0
      DN2(JPT)=DEN2
      XN2(JPT)=E2
      GO TO 105
157  J0=JPT-N1
      DO 1500 I=1,N1
      J=J0+I
1500 VR(I)=DNO(J)
      NS2=1
      NPT=NIN
      CALL LSTSQR
1502 BX=0.5
      DO 159 IN=1,25
      POL=((CFT(4)*BX+CFT(3))*BX+CFT(2))*BX+CFT(1)
      POLP=(3.0*CFT(4)*BX+2.0*CFT(3))*BX+CFT(2)
      IF(POLP) 158,1505,1505
158  IF(ABS(POL)-1.0E-07) 1507,1507,159
159  BX=BX-POL/POLP
1507 IF(NS2-1) 160,160,1511
1505 IF(NS2-1) 153,153,197
160  DO 1510 I=1,N1
      J=J0+I
1510 VR(I)=XN0(J)
      GO TO 1513
1511 DO 1512 I=1,N1
      J=J0+I
1512 VR(I)=XN2(J)
1513 CALL LSTSQR
      ES=((CFT(4)*BX+CFT(3))*BX+CFT(2))*BX+CFT(1)
      THS=V(1)+DTH*(FLOAT(NPT)*(BX-0.5)-1.0)
      IF(NS2-1) 1517,1517,1518
1517 EOS=ES
      IF(ABS(EOS)-CTF) 166,166,170

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950J7161
950J7162
950J7163
950J7164
950J7165
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950J7168
950J7169
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950J7201

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170	IF(EOS)	1000,166,161	950J7202
1000	IF(NOT-)	1001,171,1001	950J7203
1001	IF(DER(3))	171,1002,1002	950J7204
1002	U2P=U20		950J7205
	GO TO 177		950J7206
171	ESN=EOS		950J7207
	U2N=U20		950J7208
	IF(ESP)	172,172,173	950J7209
172	U20=1.005*U20		950J7210
	GO TO 100		950J7211
173	U20=U2P+(U2N-U2P)/(ESP-ESN)*ESP		950J7212
	GO TO 180		950J7213
161	ESP=EOS		950J7214
	U2P=U20		950J7215
	IF(ESN)	173,174,174	950J7216
174	IF(IPT)	176,176,175	950J7217
175	IF(EOS**2/ZNMS(IPT)-1.0)	176,177,177	950J7218
176	IPT=IPT+1		950J7219
	ZNMS(IPT)=EOS**2		950J7220
	EP(IPT)=U20		950J7221
	IF(IPT-2)	177,162,162	950J7222
162	FX=0.0		950J7223
	DO 165	1A=1,IPT	950J7224
	CFX=1.0		950J7225
	DO 164	1B=1,IPT	950J7226
	IF(1A-1B)	163,164,163	950J7227
163	CFX=CFX*(ZNMS(1A)/ZNMS(1B)-1.0)		950J7228
164	CONTINUE		950J7229
165	FX=FX+EP(1A)/CFX		950J7230
	U20=-ABSF(FX)		950J7231
	IF(U20/U2P-1.0)	178,177,177	950J7232
177	IF(U2N)	155,151,151	950J7233
151	IF(KTR-2)	1420,1420,1430	950J7234
1420	U20=(1.0-1.0E-02)*U2P		950J7235
	GO TO 100		950J7236
1430	U20=(1.0-1.0E-07)*U2P		950J7237
	GO TO 100		950J7238
178	IF(U2N)	179,100,100	950J7239
179	IF(U20/U2N-1.0)	155,155,180	950J7240
180	IF(ABSF((U2P-U2N)/UONE)-2.0E-08)	166,166,194	950J7241
194	IF(ABSF((U2P-U20)/UONE)-2.0E-08)	196,196,195	950J7242

195	IF(ABSF(U2C-U2N)/UONE)-2.0E-08)	196,196,100	950J7243
196	U20=0.5*(U2N+U2P)		950J7244
	GO TO 100		950J7245
166	DO 167 I=1,N1		950J7246
	J=J0+1		950J7247
167	VR(I)=DN2(J)		950J7248
	NS2=2		950J7249
	CALL LSTSQR		950J7250
	GO TO 1502		950J7251
C			950J7252
1518	E25=ES		950J7253
	IF(ABSF(E25)-CTF) 300,300,200		950J7254
200	KTR=KTR+1		950J7255
	IF(KTR-2) 202,202,209		950J7256
202	DM1=E25		950J7257
	DM2=U20		950J7258
	DM3=EPS0		950J7259
	IF(E25) 204,300,207		950J7260
197	KTR=KTR+1		950J7261
204	EPSUB=EPS0		950J7262
	U2UB=U20		950J7263
	IF(EPSLB) 205,205,206		950J7264
205	EPS0=0.99*EPSUB		950J7265
	GO TO 226		950J7266
206	EPS0=0.5*(EPSLB+EPSUB)		950J7267
	U20=0.5*(U2LB+U2UB)		950J7268
	GO TO 225		950J7269
207	EPSLB=EPS0		950J7270
	U2LB=U20		950J7271
	IF(EPSUB) 208,208,206		950J7272
208	EPS0=1.01*EPSLB		950J7273
	GO TO 226		950J7274
209	DM1L=DM1		950J7275
	DM2L=DM2		950J7276
	DM3L=DM3		950J7277
	DM1=E25		950J7278
	DM2=U20		950J7279
	DM3=EPS0		950J7280
	IF(E25) 210,300,211		950J7281
210	EPSUB=EPS0		950J7282
	U2UB=U20		950J7283

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211 GO TO 212
    EPSL8=EPS0
212 U2L8=U20
    RR1=1.0/(1.0-DM1/DM1L)
    EPS0=DM3L+RR1*(DM3-DM3L)
    U20=DM2L+RR1*(DM2-DM2L)
    IF(EPSUB*EPSLB) 214,214,213
213 RR2=(EPS0-EPSLB)/(EPSUB-EPSLB)
    IF(ABSF(RR2-0.5)-0.5) 225,206,206
214 IF(E2S) 215,300,216
215 IF(EPSUB-EPS0) 205,205,226
216 IF(EPS0-EPSLB) 208,208,226
225 IF(EPSUB-EPSLB-2.0E-08) 300,300,226
226 IF(KTR-25) 98,50,50
50 WRITE OUTPUT TAPE 6,25
    CALL EXIT
C
300 L1=1
    NS1=2
320 CALL PATCH(L1,L2,NDIM,JPT,DIH,ER,DNO,XNO,DM2,XN2)
    IF(L2-2) 156,700,600
700 NPT=JPT+1
    GO TO 105
600 IF(M5-1) 605,607,607
605 NS1=1
    NS3 = 2
    CTF=1000.0
    M5=1
    GO TO 101
607 NS1=3
    C14=SQRTF(1.0/(1.0/(C8*TMN**2)+1.0))
    GO TO 105
610 W0=V(4)*SQRTF(1.0+ETA**2)
    W2=SQRTF(W2S)
    W1=SQRTF(W1S)
    IF(W0-C14) 105,615,615
615 IF(W2-C14) 105,620,620
620 IF(W1-C14) 105,625,625
625 CALL POOH(3)
    CALL CPX
    END

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950J7284
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950J7299
950J7300
950J7301
950J7302
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950J7310
950J7311
950J7312
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950J7319
950J7320
950J7321
950J7322
950J7323

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SUBROUTINE CPX
* LABEL
950JJ
C
DIMENSION V(7),DER(7),VR(50),CFT(4),CF4(4),CF7(4)
DIMENSION M(10),ARRAY(12)
C
COMMON V,DER,E0,DENO,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5,
1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,
2FSMS,FSW,FSWS,PHIO,FENT,RORT,PRAT,EPSO,U20,PSI1,PHI1,PHI2,DLPP1,
3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,XO,SO,S1,S2,I0,I1,
4T2,GC,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7
C
1 FORMAT(1H1)
2 FORMAT(1H0)
3 FORMAT(3X,1P7E16.7)
C
REWIND 2
READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY
V0 = V(4)
V2 = V(7)
U0 = ETA*V0
U2 = V(6)
CC1=C1-1.0
CC2=C1/CC1
X=XO-RB*F2
Y=RB*F1
ZM=SQRTF(1.0/(C8*(1.0/V(4)**2-1.0)))
TH = 1.570796-V(1)
P = FENT*(1.0-(1.0+ETA**2)*V(4)**2)**CC2
R = FENT
ZMU = ATANF(1./SQRTF(ZM**2-1.0))
NPT = -1
DUM = 0.0
WRITE TAPE 2,X,Y,P,TH,ZMU,R,NPT,DUM,DUM,DUM
XI=0.0
NPT = 0
C
L = 10
XL = L

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```

DDX = 1.0/XL
DO 10 I=1,L
XI = XI+DDX
PHIXI=((PHI0+PHI1-2.0*PHI2)*2.0*XI+4.0*PHI2-3.0*PHI0-PHI1)*XI+PHI0
P1=PHIXI**C2
VVEL = ((VC+V1-2.0*V2)*2.0*XI+4.0*V2-3.0*V0-V1)*XI+V0
UVEL = ((U0+U1-2.0*U2)*2.0*XI+4.0*U2-3.0*U0-U1)*XI+U0
WS=UVEL**2+VVEL**2
ZM=SQRTF(1.0/(C8*(1.0/WS-1.0)))
ZMU = ATANF(1.0/SQRTF(ZM**2-1.0))
TH = 3.14159763*(.5+SIGNF(.5,UVEL))-ATANF(ABSF(VVEL/UVEL))*
1 SIGNF(1.0,UVEL)-V(1)
R = 1.0/P1
P = R*(1.0-WS)**CC2
RXI=RB+XI*V(2)
X=X0-RXI*F2
Y=RXI*F1
WRITE TAPE 2,X,Y,P,TH,ZMU,R,NPT,DUM,DUM,DUM
CONTINUE
NPT = 1
W = V(3)
REWIND 9
WRITE TAPE 9,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM
BACKSPACE 2
BACKSPACE 2
READ TAPE 2,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM
WRITE TAPE 9,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM
IF (NPT) 40,30,30
C
END FILE 9
L = L+1
REWIND 9
BACKSPACE 2
DO 50 I=1,L
READ TAPE 9,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM
WRITE TAPE 2,X,Y,P,TH,ZMU,R,NPT,W,DUM,DUM
CONTINUE
END FILE 2
REWIND 2
REWIND 9
CALL CHAIN (8,8)

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950JJ038  
950JJ039  
950JJ040  
950JJ041  
950JJ042  
950JJ043  
950JJ044  
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950JJ046  
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950JJ067  
950JJ068  
950JJ069  
950JJ070  
950JJ071  
950JJ072  
950JJ073  
950JJ074  
950JJ075  
950JJ076  
950JJ077  
950JJ078

950JJ079

RETURN  
END

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SUBROUTINE NASTY
  * LABEL
  950JP
C
  DIMENSION V(7),DER(7),PS(750),PH(750),DLP(750),VR(50),CFT(4),
  1CF4(4),CF7(4)
C
  COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5,
  1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,
  2FSMS,FSW,FSWS,PHIC,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,
  3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,
  4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTX,CF4,CF7,NPT
C
  30 FORMAT(64H0 ERROR IN ENTROPY INTERPOLATION. PROGRAM UNABLE TO
  1CONTINUE.)
C
  NPT=NPT
  IF(M2-2) 1,2,2
  M2=2
  V(1)=0.0
  V(2)=EPS0
  V(3)=1.5707963
  V(4)=0.0
  V(5)=0.0
  V(6)=U20
  V(7)=0.0
  DER(1)=1.0
  DER(2)=0.0
  DER(6)=0.0
  RB=X0
  Z=RB/EPS0
  Z1=2.0*Z+1.0
  Z2=4.0*Z+3.0
  U2S=U20**2
  F3=1.0-U2S
  TAU2=F3**C2
  H2=TAU2*U20
  DER(3)=(Q3*Z2-4.0*TAU2*Z1*(C7*F3+U2S)+C7*(4.0*Z+1.0))/Q4
  DER(4)=-Q2*DER(3)+Z2*Q1-4.0*Z1*H2
  DER(5)=-TAU2*FENT*(RB+0.5*V(2))*V(6)

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```

DER(7)=(0.5*(Q2*DER(3)-(5.0*Z+4.0)*Q1)+Z1*H2)/TAU2
NAXIS=-1
NPT=1
PS(NPT)=0.0
PH(NPT)=PHI0
DLP(NPT)=0.0
PSI1=0.0
PHI1=PHI0
DLPP1=0.0
PHI2=PHI0
DLPP2=0.0
RETURN
C
2
40
IF(NOPT-5) 50.40.50
F1=SINF(V(1))
F2=COSF(V(1))
F4=(SINF(V(3)))**2
F5=SINF(2.0*V(3))
F6=COSF(V(3))/SINF(V(3))
F7=RB+V(2)
DER(2)=-F7*COSF(V(1)+V(3))/SINF(V(1)+V(3))
Z=RB/V(2)
Z1=Z+1.0
Z2=2.0*Z+1.0
Z3=DER(2)/V(2)
C
VOS=V(4)**2
F8=1.0-VOS
RH00=(F8/PHI0)**C2
S0=0.0
T0=V(4)*F8**C2
G0=RH00*(C7*F8+VOS)
BH0=RH00*C7*F8
C
F9=1.0/(FSMS*F4)
F10=1.0-F9
WX=1.0-C6*F4*F10
WY=C3*F5*F10
DWX=-C6*F5
DWY=C6*(COSF(2.0*V(3))+F9)
XM1=FSW*(DWY*F1-DWX*F2)
950JP038
950JP039
950JP040
950JP041
950JP042
950JP043
950JP044
950JP045
950JP046
950JP047
950JP048
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950JP063
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XN1=-FSW*(DWX*F1+DWY*F2)
U1=FSW*(WY*F1-WX*F2)
U1S=U1**2
V1=FSW*(WX*F1+WY*F2)
V1S=V1**2
W1S=U1S+V1S
F11=V1*XN1-U1*XM1
F12=1.0-W1S
RHO1=C5*FS2/(1.0+FS1*F6**2)
TAU1=F12**C2
T1=TAU1*V1
H1=TAU1*U1
S1=RHO1*U1*V1
G1=RHO1*(C7*F12+V1S)
BH1=RHO1*(C7*F12+U1S)
BG1=TAU1*(V1*F11/(C8*F12)-XN1)
D1=C9*FS2*U1*V1*F5/F12+RHO1*(V1*XM1-U1*(XN1+2.0*V1*F11/F12))

C
IF(M3-1) 5,5,3
3 NPT=NPT+1
PS(NPT)=FS5*F7*F1
PH(NPT)=C12*((FS3*F4)-C13)*(1.0+1.0/(FS3*F4))**C1
5 NPT=NPT
IKT=NPT
IF(NAXIS) 22,22,6
6 IF(V(5)-PS(NPT)) 4,8,10
4 IKT=IKT-1
IF(IKT) 20,20,7
7 IF(V(5)-PS(IKT)) 4,8,9
20 WRITE OUTPUT TAPE 6,30
CALL EXIT
22 NAXIS=1
8 PH12=PH(IKT)
M4=1
GO TO 11
9 H=(V(5)-PS(IKT))/(PS(IKT+1)-PS(IKT))
PH12=PH(IKT)+H*(PH(IKT+1)-PH(IKT))
M4=2
GO TO 11
10 PS11=FS5*F7*F1
PH11=C12*((FS3*F4)-C13)*(1.0+1.0/(FS3*F4))**C1

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950JP160

H=(V(5)-PS(NPT))/(PSI1-PS(NPT))
PHI2=PH(NPT)+H*(PHI1-PH(NPT))
M4=3

C 11
U2S=V(6)**2
V2S=V(7)**2
W2S=U2S+V2S
F13=1.0-W2S
TAU2=F13**C2
RHO2=(F13/PHI2)**C2
T2=TAU2*V(7)
H2=TAU2*V(6)
G2=RHO2*(C7*F13+V2S)
S2=RHO2*V(6)*V(7)
BH2=RHO2*(C7*F13+U2S)

C
S1P=Z3*(3.0*S1-4.0*S2)-4.0*(Z*BH0+Z1*BH1-Z2*BH2)+G1-G0
S2P=0.5*(Z3*S1+5.0*Z*BH0-2.0*Z2*BH2-Z1*BH1+G0)+G2
DER(3)=(S1P-RHO1*(V1S-U1S))/D1
T1P=BG1*DER(3)-H1
TOP=T1P+Z3*(4.0*T2-T0-3.0*T1)+4.0*(Z1*H1-Z2*H2)
T2P=-0.5*T1P+2.0*Z3*(T1-T2)+Z2*H2-2.5*Z1*H1
EO=C4*(F8*(1.0-C2))*TOP
DENO=C4-VOS
DER(4)=EO/DENO
DER(5)=RHO2*(0.5*V(7)*DER(2)- (RB+0.5*V(2))*V(6))
F14=1.0/(PHI2**C2)
IF(M3-1) 13,13,12
F15=FS3*F4
DLPDS=2.0*F6*(F15-C8)**2/((1.0+F15)*(F15-C13))
DPSDTH=FS5*(DER(2)*F1+F7*F2)
DLP(NPT)=DLPDS*DER(3)/DPSDTH
IF(M4-2) 14,15,16
DLP2=DLP(1KT)
GO TO 17
DLP2=DLP(1KT)+H*(DLP(1KT+1)-DLP(1KT))
GO TO 17
F15=FS3*F4
DLPDS=2.0*F6*(F15-C8)**2/((1.0+F15)*(F15-C13))
DPSDTH=FS5*(DER(2)*F1+F7*F2)
DLP1=DLPDS*DER(3)/DPSDTH

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17   DLPP2=DLP(NPT)+H*(DLPP1-DLP(NPT))
18   IF(THT-V(1)) 18,19,19
19   DER(6)=(S2P-V(6))*F14*T2P+S2*C2*DLPP2*DER(5))/(T2*F14)
25   DEN2=C4+C6*U2S-W2S
26   E2=C6*(C8*F13*T2P+T2*V(6)*DER(6))/TAU2
27   DER(7)=E2/DEN2
28   IF(M3-1) 26,26,25
29   PS11=PS(NPT)
30   PHI1=PH(NPT)
31   DLPP1=DLP(NPT)
32   IF(M6-1) 27,27,28
33   RETURN
34   ZET=V(1)-THX
35   DER(4)=(CF4(4)*ZET+CF4(3))*ZET+CF4(2))*ZET+CF4(1)
36   DER(7)=(CF7(4)*ZET+CF7(3))*ZET+CF7(2))*ZET+CF7(1)
37   RETURN
38
39   C
40   F1=SINF(V(1))
41   F2=COSF(V(1))
42   F4=SINF(V(3))*2
43   F5=SINF(2.0*V(3))
44   F6=COSF(V(3))/SINF(V(3))
45   CALL BODY
46   F7=RB+V(2)
47   DER(2)=-ETA*RB-F7*COSF(V(1)+V(3))/SINF(V(1)+V(3))
48   Z=RB/V(2)
49   Z1=Z+1.0
50   Z2=2.0*Z+1.0
51   Z3=DER(2)/V(2)
52   Z4=ETA*Z
53
54   C
55   U0=ETA*V(4)
56   U0S=U0**2
57   V0S=V(4)**2
58   W0S=U0S+V0S
59   F8=1.0-W0S
60   A0S=C8*F8
61   TAU0=F8**C2
62   RH00=TAU0*FENT
63   T0=TAU0*V(4)
64   H0=TAU0*U0

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	S0=RHOC*U0*V(4)	950JP202
	G0=RH00*(C7*F8+V0S)	950JP203
	BH0=RH00*(C7*F8+U0S)	950JP204
		950JP205
	F9=1.0/(FSMS*F4)	950JP206
	F10=1.0-F9	950JP207
	WX=1.0-C6*F4*F10	950JP208
	WY=C3*F5*F10	950JP209
	DWX=-C6*F5	950JP210
	DWY=C6*(COSF(2.0*V(3))+F9)	950JP211
	XM1=FSW*(DWY*F1-DWX*F2)	950JP212
	XN1=-FSW*(DWX*F1+DWY*F2)	950JP213
	U1=FSW*(WY*F1-WX*F2)	950JP214
	U1S=U1**2	950JP215
	V1=FSW*(WX*F1+WY*F2)	950JP216
	V1S=V1**2	950JP217
	W1S=U1S+V1S	950JP218
	F11=V1*XN1-U1*XM1	950JP219
	F12=1.0-W1S	950JP220
	RH01=C5*FS2/(1.0+FS1*F6**2)	950JP221
	TAU1=F12**C2	950JP222
	T1=TAU1*V1	950JP223
	H1=TAU1*U1	950JP224
	S1=RH01*U1*V1	950JP225
	G1=RH01*(C7*F12+V1S)	950JP226
	BH1=RH01*(C7*F12+U1S)	950JP227
	BG1=TAU1*(V1*F11/(C8*F12)-XN1)	950JP228
	D1=C9*FS2*U1*V1*F5/F12+RH01*(V1*XM1-U1*(XN1+2.0*V1*F11/F12))	950JP229
		950JP230
	IF(M3-1) 55,55,53	950JP231
	NPT=NPT+1	950JP232
	PS(NPT)=FS5*F7*F1	950JP233
	PH(NPT)=C12*((FS3*F4)-C13)*(1.0+1.0/(FS3*F4))**C1	950JP234
	NPT=NPT	950JP235
	IKT=NPT	950JP236
	IF(NAXIS) 72,72,56	950JP237
	IF(V(5)-PS(NPT)) 54,58,60	950JP238
	IKT=IKT-1	950JP239
	IF(IKT) 20,20,57	950JP240
	IF(V(5)-PS(IKT)) 54,58,59	950JP241
	NAXIS=1	950JP242

C

C

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58      PHI2=PH(IKT)
      M4=1
      GO TO 61
59      H=(V(5)-PS(IKT))/(PS(IKT+1)-PS(IKT))
      PHI2=PH(IKT)+H*(PH(IKT+1)-PH(IKT))
      M4=2
      GO TO 61
60      PS11=FS5*F7*F1
      PHI1=C12*((FS3*F4)-C13)*(1.0+1.0/(FS3*F4))*C1
      H=(V(5)-PS(NPT))/(PS11-PS(NPT))
      PHI2=PH(NPT)+H*(PH11-PS(NPT))
      M4=3
      U2S=V(6)**2
      V2S=V(7)**2
      W2S=U2S+V2S
      F13=1.0-W2S
      TAU2=F13**C2
      RHO2=(F13/PHI2)**C2
      T2=TAU2*V(7)
      H2=TAU2*V(6)
      G2=RHO2*(C7*F13+V2S)
      S2=RHO2*V(6)*V(7)
      BH2=RHO2*(C7*F13+U2S)

      A2=4.0*(Z4*(2.0*T2-T1-T0)+Z*H0-Z2*H2+Z1*H1)-Z3*(T0-4.0*T2+3.0*T1)
      B2=4.0*(Z4*(2.0*S2-S1-S0)+Z*BH0-Z2*BH2+Z1*BH1)-Z3*(S0-4.0*S2+3.0*S1)+G0-G1
      DENO=C4-WOS
      TERM=DENO+C6*AOS
      DER(3)=(FENT*(ETAP*(DENO+C6*UOS)*T0*V(4)+U0*TERM*(A2-H1))-
      1DENO*(RHO1*(V1S-U1S)+B2))/(DENO*D1-TERM*U0*FENT*BGL)
      SOP=RHO1*(V1S-U1S)+D1*DER(3)+B2
      S2P=0.5*(Z*BH0-5.0*Z1*BH1+G1-S1P-Z4*(S0+4.0*S2-5.0*S1))+G2
      1+Z2*BH2+2.0*Z3*(S1-S2)
      T1P=BG1*DER(3)-H1
      TOP=T1P+A2
      T2P=0.5*(Z*H0-5.0*Z1*H1-T1P-Z4*(T0+4.0*T2-5.0*T1))+Z2*H2
      1+2.0*Z3*(T1-T2)
      EO=C6*(AOS*TOP/TAU0+U0*VOS*ETAP)
      DER(4)=EO/DENO

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DER(5)=RHO2\*(V(7)\*(ETA\*RB+0.5\*DER(2))-(RB+0.5\*V(2))\*V(6))  
GO TO 23  
END

950JP284  
950JP285  
950JP286

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SUBROUTINE PATCH(L1,L2,NDIM,JPT,DTH,ER,DNO,XNO,DN2,XN2)
  * 950JK
  LABEL
  C
  DIMENSION V(7),DER(7),ER(7),ERE(7),VE(7),CF4(4),CF7(4),DNO(750),
  1XNO(750),DN2(750),XN2(750)
  DIMENSION VR(50),CFT(4)
  C
  COMMON V,DER,E0,DENO,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5,
  1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,
  2FSMS,FSW,FSWS,PHIO,FENT,RORT,PRAT,EPSO,U20,PSI1,PHI1,PHI2,DLPP1,
  3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,XO,S0,S1,S2,T0,T1,
  4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7,NPT
  C
  2 FORMAT(1H1)
  3 FORMAT(6E12.7)
  4 FORMAT(3X,1P7E16.7)
  5 FORMAT(1H0)
  7 FORMAT(5X,4HIC0=I4,5X,4HIC2=I4)
  10 FORMAT(1H0,4X,27HUNABLE TO CONVERGE PATCHING)
  C
  EOWIGL=EOWIG
  E2WIGL=E2WIG
  EOWIG=DER(4)*DENO
  E2WIG=DER(7)*DEN2
  WRITE OUTPUT TAPE 6,4,V(1),E0,EOWIG,E2,E2WIG
  IF(L1-1) 300,300,320
  300 DO 310 J=1,7
  VE(J)=V(J)
  310 ERE(J)=ER(J)
  L1=2
  M6=2
  JD0=0
  JD2=0
  NBR=0
  IC2=1
  NTR=1
  MPT=JPT
  THX=V(1)
  TDT=2.0*DTH

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311 IF(M5) 312,312,311
    CUT1=1000.0
    CUT2=CUT1
    GO TO 156
312 CF4(1)=DER(4)
    CF4(2)=(DER(4)-XN0(JPT-1)/DNO(JPT-1))/(2.0*DTH)
    CF4(3)=0.0
    CF4(4)=0.0
    CF7(1)=DER(7)
    CF7(2)=(DER(7)-XN2(JPT-1)/DN2(JPT-1))/(2.0*DTH)
    CF7(3)=CF7(2)/(4.0*DTH)+(XN2(JPT-3)/DN2(JPT-3)-DER(7))/(4.0*DTH)**2
    CF7(4)=0.0
    CUT1=1.0E-05
    CUT2=1.0E-05
315 WRITE OUTPUT TAPE 6,5
    WRITE OUTPUT TAPE 6,4,(CF4(J),J=1,4)
    WRITE OUTPUT TAPE 6,4,(CF7(J),J=1,4)
    GO TO 156
320 IF(DEN0) 330,340,350
330 IF(JD0) 340,340,350
340 A1=DNO(JPT)*DNO(JPT-1)/((DENO-DNO(JPT))*(DENO-DNO(JPT-1)))
    A2=DENO*DNO(JPT-1)/((DNO(JPT)-DENO)*(DNO(JPT)-DNO(JPT-1)))
    A3=DENO*DNO(JPT)/((DNO(JPT-1)-DENO)*(DNO(JPT-1)-DNO(JPT)))
    TH0S=V(1)*A1+(V(1)-DTH)*A2+(V(1)-2.0*DTH)*A3
    EOS=E0*A1+XN0(JPT)*A2+XN0(JPT-1)*A3
    WRITE OUTPUT TAPE 6,4,TH0S,E0S
    JD0=1
350 IF(DEN2) 360,360,156
360 IF(JD2) 370,370,375
370 A1=DN2(JPT)*DN2(JPT-1)/((DEN2-DN2(JPT))*(DEN2-DN2(JPT-1)))
    A2=DN2*DN2(JPT-1)/((DN2(JPT)-DEN2)*(DN2(JPT)-DN2(JPT-1)))
    A3=DN2*DN2(JPT)/((DN2(JPT-1)-DEN2)*(DN2(JPT-1)-DN2(JPT)))
    TH2S=V(1)*A1+(V(1)-DTH)*A2+(V(1)-2.0*DTH)*A3
    E2S=E2*A1+XN2(JPT)*A2+XN2(JPT-1)*A3
    WRITE OUTPUT TAPE 6,4,TH2S,E2S
    JD2=1
372 IF(NBR) 372,372,375
    FAT=1.0-(V(1)-TH2S)/DTH
    FOR=XN0(JPT)+(E0-XN0(JPT))*FAT
    FOW=EOWIGL+(EOWIG-EOWIGL)*FAT
    FOS=FOR-FOW

```

375	IF(JD2-JD0) 156,380,156	950JK079
380	IF(ABSF(EOS)-CUT1) 390,390,400	950JK080
390	IF(ABSF(E2S)-CUT1) 500,500,400	950JK081
400	NBR=NBR+1	950JK082
410	IF(NBR-2) 410,420,430	950JK083
	CF7L=CF7(2)	950JK084
	EOSLL=EOS	950JK085
	E2SLL=E2S	950JK086
	CF7(2)=0.99*CF7L	950JK087
	GO TO 440	950JK088
420	CF4L=CF4(2)	950JK089
	EOSL=EOS	950JK090
	E2SL=E2S	950JK091
	CF4(2)=1.01*CF4L	950JK092
	GO TO 440	950JK093
430	IF(NTR-15) 435,50,50	950JK094
50	WRITE OUTPUT TAPE 6,10	950JK095
	CALL EXIT	950JK096
435	NTR=NTR+1	950JK097
	NBR=0	950JK098
	DEOD4=(EOS-EOSL)/(CF4(2)-CF4L)	950JK099
	DE2D4=(E2S-E2SL)/(CF4(2)-CF4L)	950JK100
	DEOD7=(EOSL-EOSLL)/(CF7(2)-CF7L)	950JK101
	DE2D7=(E2SL-E2SLL)/(CF7(2)-CF7L)	950JK102
	DCF4=(E2SLL/DE2D7-EOSLL/DEOD7)/(DEOD4/DEOD7-DE2D4/DE2D7)	950JK103
	DCF7=(E2SLL/DE2D4-EOSLL/DEOD4)/(DEOD7/DEOD4-DE2D4/DE2D4)	950JK104
	WRITE OUTPUT TAPE 6,4,EOSLL,EOSL,EOS,E2SLL,E2SL,E2S,CF4L,CF4(2),CF7(2),DCF7	950JK105
	17L,CF7(2),DEOD4,DE2D4,DEOD7,DE2D7,DCF4,DCF7	950JK106
	CF4(2)=CF4L+DCF4	950JK107
	CF7(2)=CF7L+DCF7	950JK108
	WRITE OUTPUT TAPE 6,5	950JK109
	WRITE OUTPUT TAPE 6,4,CF4(2),CF7(2)	950JK110
C		950JK111
440	DO 450 J=1,7	950JK112
	V(J)=VE(J)	950JK113
450	ER(J)=ERE(J)	950JK114
	M3=2	950JK115
	M6=1	950JK116
	IF(NDIM) 460,460,465	950JK117
460	CALL NASTY	950JK118
	GO TO 470	950JK119

465	CALL MESSY	950JK120
470	M6=2	950JK121
	JPT=MPT	950JK122
	JD0=0	950JK123
	JD2=0	950JK124
	WRITE OUTPUT TAPE 6,2	950JK125
	L2=2	950JK126
	RETURN	950JK127
C		950JK128
500	NTR=1	950JK129
	IC2=IC2+1	950JK130
	WRITE OUTPUT TAPE 6,5	950JK131
	WRITE OUTPUT TAPE 6,7,IC0,IC2	950JK132
	WRITE OUTPUT TAPE 6,4,TH2S,F0R,F0W,F0S	950JK133
	IF(ABSF(F0S)-CUT2) 600,600,502	950JK134
502	IF(IC2=2) 505,505,510	950JK135
505	BF7L=CF7(3)	950JK136
	CF7(3)=BF7L-0.1	950JK137
	F0SL=F0S	950JK138
	WRITE OUTPUT TAPE 6,4,BF7L,F0SL	950JK139
	GO TO 440	950JK140
510	IF(IC2=15) 515,515,50	950JK141
515	F0SP=(F0S-F0SL)/(CF7(3)-BF7L)	950JK142
	BF7L=CF7(3)	950JK143
	F0SL=F0S	950JK144
	CF7(3)=BF7L-F0SL/F0SP	950JK145
	WRITE OUTPUT TAPE 6,4,BF7L,F0SL	950JK146
	GO TO 440	950JK147
C		950JK148
156	L2=1	950JK149
	RETURN	950JK150
600	L2=3	950JK151
	RETURN	950JK152
	END	

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SUBROUTINE POOH(J)
  * LABEL
  950JL
C
  DIMENSION V(7),DER(7),VR(50),CFT(4),CF4(4),CF7(4)
  DIMENSION BL(2,300)
  DIMENSION BBB(10,100),M(10),ARRAY(12)
C
  COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5,
  1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,
  2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EP50,U20,PSI1,PHI1,PHI2,DLPP1,
  3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,
  4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTX,CF4,CF7
C
  ZMACHF(X)=SORTF(1.0/(C8*(1.0/X-1.0)))
C
  CC2=C1*CC2
  IF(J-2) 1,10,20
  X=-EPSO
  Y=0.0
  U1S=(FSW*(1.0-C6*(1.0-1.0/FSMS)))*2
  P=FENT*(1.0-U1S)**CC2
  DEL=0.0
  ZM=ZMACHF(U1S)
  K=1
  REWIND 3
  CALL SPMOVE (X,Y,P,DEL,ZM,FENT,K,V(3),BBB,1)
  X=-EPSO/2.0
  U2S=V(6)**2
  P=FENT*(1.0-U2S)**CC2
  ZM=ZMACHF(U2S)
  K=0
  DUM=0.0
  CALL SPMOVE (X,Y,P,DEL,ZM,FENT,K,DUM,BBB,2)
  X=0.0
  DEL=1.5707963
  K=-1
  CALL SPMOVE (X,Y,FENT,DEL,X,FENT,K,DUM,BBB,3)
  NRL=1
  BL(1,1)=0.0

```

```

          BL(2,1) = 0.0
          WRITE TAPE 3,BBB
          RETURN
C 10
          NRL=NRL+1
          BL(1,NRL)=V(1)
          BL(2,NRL) =V(4)/FSW
          RXI=1.0+V(2)
          X=1.0-RXI*F2
          Y=RXI*F1
          R=PHI1*(-C2)
          P=R*(1.0-W1S)**CC2
          ZM=ZMACHF(W1S)
          DEL=3.14159763*(0.5+SIGNF(0.5,U1))-ATANF(ABSF(V1/U1))*SIGNF(1.0,U1)
          1)-V(1)
          K=1
          CALL SPMOVE (X,Y,P,DEL,ZM,R,K,V(3),BBB,1)
          RXI=1.0+0.5*V(2)
          X=1.0-RXI*F2
          Y=RXI*F1
          R=PHI2*(-C2)
          P=R*(1.0-W2S)**CC2
          DEL=3.14159763*(0.5+SIGNF(0.5,V(6)))-ATANF(ABSF(V(7)/V(6)))*SIGNF(
          11.0,V(6))-V(1)
          ZM=ZMACHF(W2S)
          K=0
          CALL SPMOVE (X,Y,P,DEL,ZM,R,K,DUM,BBB,2)
          X=1.0-F2
          Y=F1
          WOS=V(4)**2
          P=FENT*(1.0-WOS)**CC2
          DEL=1.5707963-V(1)
          ZM=ZMACHF(WOS)
          K=-1
          CALL SPMOVE (X,Y,P,DEL,ZM,FENT,K,DUM,BBB,3)
          WRITE TAPE 3,BBB
          RETURN
C 20
          REWIND 2
          READ TAPE 2,C1,FSM,FSP,FST,M,ARRAY
          RBAR = 1.0

```

950JL079  
950JL080  
950JL081  
950JL082

```
REWIND 2  
WRITE TAPE 2,C1,FSM,FSP,FST,M,ARRAY,RBAR,DUM,DUM,BBB,BBB,  
1  NRL,((BL(N,M),N=1,2),M=1,NRL)  
RETURN  
END
```

```

C
SUBROUTINE BODY
C
DIMENSION V(7),DER(7),VR(50),CFT(4),CF4(4),CF7(4)
C
COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5,
1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,
2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPPI,
3DLPPI,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,
4T2,G0,G1,G2,W2S,W1S,V1,U1,M5,M6,THX,DTHX,CF4,CF7
C
GO TO(30,40,50,60,100),NOPT
C
30 CT4=CT1*F2
XI=(CT4+SQRTF(CT4**2-CT2*(1.0-(CT3*F1**2)))/(1.0-(CT3*F1**2)))
35 CT5=XI*CT3
CT6=CT2-XI*CT4
ETA=XI*F1*(CT1-CT5*F2)/CT6
ETAP=XI*(F2*((CT1*ETA-2.0*CT5*F1)*ETA+CT1-2.0*CT5*F2)+XI*(CT3)/CT6
RB=XI*A
RETURN
C
40 XI=CT1/(F2+SQRTF(1.0+CT2*F1**2))
CT3=XI*F2
CT4=CT1-CT3
CT5=XI*F1
ETA=CT5*(1.0-CT3)/CT4
ETAP=XI*(F2*((ETA-2.0*CT5)*ETA+1.0-2.0*CT3)+XI)/CT4
RB=XI*2.0*A
RETURN
C
50 RB=X0/F2
ETA=F1/F2
ETAP=1.0/(F2**2)
100 RETURN
C
60 CT4=CT1*F2
XI=CT2/(CT4+SQRTF(CT4**2-CT2*(1.0-CT3*F1**2)))
GO TO 35
END
950JMM00
950JMM01
950JMM02
950JMM03
950JMM04
950JMM05
950JMM06
950JMM07
950JMM08
950JMM09
950JMM10
950JMM11
950JMM12
950JMM13
950JMM14
950JMM15
950JMM16
950JMM17
950JMM18
950JMM19
950JMM20
950JMM21
950JMM22
950JMM23
950JMM24
950JMM25
950JMM26
950JMM27
950JMM28
950JMM29
950JMM30
950JMM31
950JMM32
950JMM33
950JMM34
950JMM35
950JMM36
950JMM37
950JMM38

```

```

SUBROUTINE LSTSQR
  DIMENSION V(7),DER(7),VR(50),CFT(4),CF4(4),CF7(4)
  COMMON V,DER,E0,DEN0,E2,DEN2,RB,ETA,ETAP,M1,M2,M3,C1,C2,C3,C4,C5,
  1C6,C7,C8,C9,C10,C11,C12,C13,FS1,FS2,FS3,FS4,FS5,Q1,Q2,Q3,Q4,FSM,
  2FSMS,FSW,FSWS,PHI0,FENT,RORT,PRAT,EPS0,U20,PSI1,PHI1,PHI2,DLPP1,
  3DLPP2,THT,VR,CFT,NFT,F1,F2,CT1,CT2,CT3,NOPT,A,B,X0,S0,S1,S2,T0,T1,
  4T2,G0,G1,G2,W2S,WLS,V1,U1,M5,M6,THX,DTHX,CF4,CF7
  N1=NFT+1
  N2=NFT/2+1
  BN=NFT/2
  BN1=BN+1.0
  SX0=N1
  SX2=BN1*(2.0*BN+1.0)/(12.0*BN)
  SX4=BN1*((6.0*BN+9.0)*BN+1.0)*BN-1.0)/(240.0*BN**3)
  SX6=BN1*((6.0*BN+15.0)*BN+6.0)*BN-6.0)*BN-1.0)/(1344.0*BN**5)
  1BN**5)
  SY0=0.0
  SY1=0.0
  SY2=0.0
  SY3=0.0
  DO 10 I=1,N1
    TJ=I-N2
    SY0=SY0+VR(I)
    SY1=SY1+VR(I)*TJ
    SY2=SY2+VR(I)*TJ**2
    SY3=SY3+VR(I)*TJ**3
  SN=NFT
  SY1=SY1/SN
  SY2=SY2/(SN**2)
  SY3=SY3/(SN**3)
  CFT(1)=(SY0/SX2-SY2/SX4)/(SX0/SX2-SX2/SX4)
  CFT(2)=(SY1/SX4-SY3/SX6)/(SX2/SX4-SX4/SX6)
  CFT(3)=(SY0/SX0-SY2/SX2)/(SX2/SX0-SX4/SX2)
  CFT(4)=(SY1/SX2-SY3/SX4)/(SX4/SX2-SX6/SX4)
  RETURN
  END

```

```

950JRR00
950JRR01
950JRR02
950JRR03
950JRR04
950JRR05
950JRR06
950JRR07
950JRR08
950JRR09
950JRR10
950JRR11
950JRR12
950JRR13
950JRR14
950JRR15
950JRR16
950JRR17
950JRR18
950JRR19
950JRR20
950JRR21
950JRR22
950JRR23
950JRR24
950JRR25
950JRR26
950JRR27
950JRR28
950JRR29
950JRR30
950JRR31
950JRR32
950JRR33
950JRR34
950JRR35
950JRR36
950JRR37

```

```

* SUBROUTINE SPMOVE (X,Y,P,TH,ZM,R,NPT,W,E,IB)
  LABEL
950JGG
    DIMENSION B(10,100)
    B(1,IB) = X
    EQUIVALENCE (XNPT,NPT1)
    NPT1 = NPT
    B(2,IB) = Y
    B(3,IB) = P
    B(4,IB) = TH
    B(5,IB) = ZM
    B(6,IB) = R
    B(7,IB) = XNPT
    B(8,IB) = W
    RETURN
  END
950JGG01
950JGG02
950JGG03
950JGG04
950JGG05
950JGG06
950JGG07
950JGG08
950JGG09
950JGG10
950JGG11
950JGG12

```

```

C      MAIN PROGRAM CHAIN VIII - TURNING VANE.
*      LABEL
950J8
C      PROGRAM TO START CALCULATION FROM INITIAL VALUE
C      LINE.
C
      DIMENSION IND(100),X(100),Y(100)
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),
1      XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)
      DIMENSION AC1(6,20),AC2(6,20)
      DIMENSION ARRAY(12)
      DIMENSION BU(10,100),WU(10,100)
      DIMENSION BBB(2,100)
C
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2
      COMMON GAMMA,FSM,FSP,FST,SW
C
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(
15),ZMU1),
2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),
3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),
4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),
5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),
6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),
7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),
1 ZMU3A)
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),
1 (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),
2 (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),
3 (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),
4 (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),
5 (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),
8 (XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),
1 ZMU3B),
9 (XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),
6 (XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)
      EQUIVALENCE (X1(10),NPONT1),(X2(10),NPONT2),
1 (X3(10),NPONT3),(X5(10),NPONT5)
C
400  FORMAT (1H1,1'X1HX,16X1HY,32X1HA,16X1HB,16X1HC,16X1HD//)

```

```

409 C  FORMAT (1P2E17.7/52X,1P4E17.7)
      DO 5 I=1,100
      IND(I) = 0
      IP = 2
      REWIND 2
      REWIND 3
      READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R1,B,B,NRL
      1 ((BBB(M,L),M=1,2),L=1,NRL)
      CALL PAGE2 (C,ARRAY)
      REWIND 9
      DO 6 I=1,NRL
      READ TAPE 3,B
      WRITE TAPE 9,B
      CONTINUE
      REWIND 3
      REWIND 4
      DO 10 I=1,100
      READ TAPE 2,(BU(J,I),J=1,10)
      IF (BU(7,I)) 20,10,10
      CONTINUE
      10 C
      SW = .2*(SQRTF((BU(1,1)-BU(1,I))**2+(BU(2,1)-BU(2,I))**2))
      CALL DMOVE (B,BU)
      CALL DMOVE (B(1,2),BU)
      NPT1 = 12345
      CALL DMOVE (B(1,3),XX1)
      C
      NN = 1
      NN = NN+1
      CALL CHLIN8 (B,W,BU,1.0,GAMMA,NN,SW,FSM)
      DO 35 I=1,100
      DO 35 J=1,10
      B(J,I) = W(J,I)
      CONTINUE
      35 C
      IF (BU(7,NN))40,30,30
      SENSE LIGHT 1
      NT = 0
      REWIND 2
      40

```

```

950J8038
950J8039
950J8040
950J8041
950J8042
950J8043
950J8044
950J8045
950J8046
950J8047
950J8048
950J8049
950J8050
950J8051
950J8052
950J8053
950J8054
950J8055
950J8056
950J8057
950J8058
950J8059
950J8060
950J8061
950J8062
950J8063
950J8064
950J8065
950J8066
950J8067
950J8068
950J8069
950J8070
950J8071
950J8072
950J8073
950J8074
950J8075
950J8076
950J8077
950J8078

```

```

1 WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R1,B,BU,NRL,
  1({BBB(M,L),M=1,2},L=1,NRL)
  CALL NEWBDY (RBAR,B,RAD1,X,Y,N1,XCNTR,YOPEN)
  NPT1 = 12345
  RBAR = RAD1/RBAR
  REWIND 9
  DO 45 I=1,NRL
  READ TAPE 9,WU
  IF (I-IP*(I/IP)) 41,45,41
41 DO 42 J=1,3
  WU(1,J) = (WU(1,J)-RBAR)*RRBAR+XCNTR
  WU(2,J) = ABSF(YOPEN-WU(2,J)*RRBAR)
  WU(4,J) = -WU(4,J)
  WU(8,J) = -WU(8,J)
42 CONTINUE
  CALL DMOVE (WU(1,4),XX1)
  CALL STORE (BU,WU,3,M,ARRAY)
45 CONTINUE
  CALL STORE (WU,B,3,M,ARRAY)
  S1 = SINFB(4,1)/COSFB(4,1)
  IND(N1-1) = 1
  IND(2) = 1
  CALL CUBIC (X,Y,IND,N1,S1,S2,AC1)
  NN = N1
  N = 0
C 70 WRITE OUTPUT TAPE 6,400
  DO 100 I=2,NN
  IF (N) 80,80,90
80 WRITE OUTPUT TAPE 6,409,X(I-1),Y(I-1),AC1(2,I-1),AC1(3,I-1),
  11), AC1(4,I-1),AC1(5,I-1)
  GO TO 100
C 90 WRITE OUTPUT TAPE 6,409,X(I-1),Y(I-1),AC2(2,I-1),AC2(3,I-1),
  11), AC2(4,I-1),AC2(5,I-1)
C 100 CONTINUE
  IF (N) 110,110,120
110 N = 1
  WRITE OUTPUT TAPE 6,409,X(N1),Y(N1)
  CALL NEWBDY (RBAR,W,RAD2,X,Y,N2,XCNTR,YOPEN)
950J8079
950J8080
950J8081
950J8082
950J8083
950J8084
950J8085
950J8086
950J8087
950J8088
950J8089
950J8090
950J8091
950J8092
950J8093
950J8094
950J8095
950J8096
950J8097
950J8098
950J8099
950J8100
950J8101
950J8102
950J8103
950J8104
950J8105
950J8106
950J8107
950J8108
950J8109
950J8110
950J8111
950J8112
950J8113
950J8114
950J8115
950J8116
950J8117
950J8118
950J8119

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```

121
REWIND 9
RRBAR = RAD2/RBAR
DO 130 I=1,NRL
  READ TAPE 9,WU
  IF (I-IP*(1/IP)) 111,130,111
111 DO 125 J=1,3
  WU(1,J) = (WU(1,J)-RBAR)*RRBAR+XCNTR
  WU(2,J) = ABSF(YOPEN-WU(2,J)*RRBAR)
125 CONTINUE
  CALL DMOVE (WU(1,4),XX1)
  CALL STORE (BU,WU,4,M,ARRAY)
130 CONTINUE
DO 131 I=1,100
131 IND(I) = 0
NN = N2
S1 = SIN(W(4,1))/COS(W(4,1))
IND(N2-1) = 1
IND(2) = 1
CALL CUBIC (X,Y,IND,N2,S1,S2,AC2)
GO TO 70
120 WRITE OUTPUT TAPE 6,409,X(N2),Y(N2)
  CALL STORE (B,W,4,M,ARRAY)
  N1 = N1-1
  N2 = N2-1
  REWIND 2
  READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,DUM,B,BU
  1,N,((BBB(M,L),M=1,2),L=1,N)
  REWIND 2
  WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,RAD1,RAD2,B,BU
  1,N,((BBB(M,L),M=1,2),L=1,N)
  WRITE TAPE 2,AC1,AC2,N1,N2
  CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM,DUM)
C
60 CALL CHAIN (2,8)
999 CALLDUMP
END
950J8120
950J8121
950J8122
950J8123
950J8124
950J8125
950J8126
950J8127
950J8128
950J8129
950J8130
950J8131
950J8132
950J8133
950J8134
950J8135
950J8136
950J8137
950J8138
950J8139
950J8140
950J8141
950J8142
950J8143
950J8144
950J8145
950J8146
950J8147
950J8148
950J8149
950J8150
950J8151
950J8152
950J8153
950J8154

```

```

SUBROUTINE CHLIN8 (B,W,BU,TT,GAMMA,NN,SWL,FSM)
  LABEL
  * 950JM
  C
  C TT NEGATIVE -- UPPER BODY
  C TT POSITIVE -- LOWER BODY
  C THE BU ARRAY CONTAINS THE INITIAL VALUE LINE.
  C
  C DIMENSION B(10,100),W(10,100),BU(10,100),XX1U(10),XX1(10),
  1 XX3(10),XX3U(10)
  C EQUIVALENCE (NPT1,XX1(7)),(NPT3,XX3(7))
  C
  C IW = 1
  C IB = 0
  C T = TT
  C C1 = GAMMA
  C N = NN
  C SW = SWL
  C CALL DMOVE (W,BU(1,N))
  C
  C IF (T) 10,10,20
  10 NPT = 2
  C GO TO 30
  20 NPT = 1
  C
  C IW = IW+1
  30 IB = IB+1
  C CALL DMOVE (XX1,B(1,IB))
  40 IF (NPT1-NPT) 50,40,80
  50 IF (T) 60,60,70
  C
  60 CALL FDPT (B(1,IB),W(1,IW-1),W(1,IW),C1,M1)
  C GO TO 30
  70 CALL FDPT (W(1,IW-1),B(1,IB),W(1,IW),C1,M1)
  C GO TO 30
  C
  80 CONTINUE
  C XX1U(1) = B(1,IB-2)
  C XX1U(2) = B(2,IB-2)
  C CALL SHOCK (2,M1,T,XXA,XXB,XX1U,B(1,IB-2),W(1,IW-1),XX3U,XX3,XX5,
950JM000
950JM
950JM001
950JM002
950JM003
950JM004
950JM005
950JM006
950JM007
950JM008
950JM009
950JM010
950JM011
950JM012
950JM013
950JM014
950JM015
950JM016
950JM017
950JM018
950JM019
950JM020
950JM021
950JM022
950JM023
950JM024
950JM025
950JM026
950JM027
950JM028
950JM029
950JM030
950JM031
950JM032
950JM033
950JM034
950JM
950JM035
950JM036

```

```

1  C1,SW,FSM)
M1 = M1
GO TO (100,999,999,999,999,90,90),M1
90 IF (SWL/SW-4.0) 95,105,105
95 SW = SW/2.0
GO TO 80
C
100 NPT3 = NPT
CALL DMOVE (B(1,IB-2),XX3)
CALL DMOVE (W(1,IW),XX3)
IF (T) 101,101,102
101 CALL FDPT (W(1,IW),W(1,IW-1),W(1,IW+1),C1,M1)
IW = IW+2
GO TO 80
102 CALL FDPT (W(1,IW-1),W(1,IW),W(1,IW+1),C1,M1)
IW = IW+2
GO TO 80
999 CALL DUMP
C
105 NPT1 = 12345
CALL DMOVE (W(1,IW),XX1)
RETURN
END

```

```

950JM037
950JM038
950JM039
950JM040
950JM041
950JM042
950JM043
950JM044
950JM045
950JM046
950JM047
950JM048
950JM049
950JM050
950JM051
950JM052
950JM053
950JM054
950JM055
950JM056
950JM057
950JM058

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```

* 950JN
SUBROUTINE NEWBDY (RBAR,B,RADIUS,X,Y,NN1,XCNTR,YCNTR)
  LABEL
  950JN
  DIMENSION X(100),Y(100),B(10,100),XX1(10)
  EQUIVALENCE (XX1(7),NPT1)
  3   FORMAT (3X,1P7E16.7)
  401  FORMAT (6E10.5)
  400  FORMAT (4(2E8.5,12))
  404  FORMAT (15,5E10.5)
  RBAR = 1.0
  READ INPUT TAPE 5,404,N1,RADIUS,T ANGLE,XCNTR,YCNTR
  NN1 = N1+2
  READ INPUT TAPE 5,401,(X(I),Y(I),I=3,NN1)
  T ANGLE = T ANGLE/57.29578
  IF (T ANGLE) 20,20,10
  10  S1 = 1.0
      GO TO 30
  20  S1 = -1.0
  30  RBAR = RADIUS/RBAR
      T1 = COSF(T ANGLE)
      T2 = SIN(F(T ANGLE)
      T3 = RADIUS/50.0
      X(2) = XCNTR-RADIUS*T1
      Y(2) = YCNTR+RADIUS*T2
      X(3) = X(2)+T3
      Y(3) = Y(2)+T3 *T1/T2
      DO 50 I=1,100
      CALL DMOVE (XX1,B(1,I))
      IF (NPT1-12345) 40,60,40
  40  CONTINUE
      B(1,I) = (B(1,I)-RBAR)*RRBAR+XCNTR
      B(2,I) = ABSF(YCNTR-B(2,I)*RRBAR)
      B(4,I) = SIGNF(B(4,I),S1)
      B(8,I) = SIGNF(B(8,I),S1)
  50  CONTINUE
      IF (S1) 65,68,68
  60  CALL DMOVE (XX1,B(1,I))
  65  NPT1 = -2
      CALL DMOVE (B(1,I),XX1)
      DO 67 I=2,100

```

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950JN000
950JN
950JN001
950JN002
950JN003
950JN004
950JN005
950JN006
950JN007
950JN008
950JN009
950JN010
950JN011
950JN012
950JN013
950JN014
950JN015
950JN016
950JN017
950JN018
950JN019
950JN020
950JN021
950JN022
950JN023
950JN024
950JN025
950JN026
950JN027
950JN028
950JN029
950JN030
950JN031
950JN032
950JN033
950JN034
950JN035
950JN036
950JN037

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66	CALL DMOVE (XX1,B(1,I))	950JN038
	IF (NPT1-1) 67,66,68	950JN039
	NPT1 = 2	950JN040
	CALL DMOVE (B(1,I),XX1)	950JN041
67	CONTINUE	950JN042
68	X(1) = B(1,1)	950JN043
	Y(1) = B(2,1)	950JN044
	IF (B(1,1)-X(3)) 70,62,62	950JN045
62	WRITE OUTPUT TAPE 6,410	950JN046
410	FORMAT (32H THE FIRST POINT OF THE BODY IS	950JN047
	1 32HUPSTREAM OF THE BLUNT BODY DATA.)	950JN048
	CALL DUMP	950JN049
70	CONTINUE	950JN050
	RETURN	950JN051
	END	

```

C
C
      MAIN PROGRAM SECOND CHAIN - TURNING VANE
      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),
1      XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)
      DIMENSION AC1(6,20),AC2(6,20)
      DIMENSION XX1U(10),XX3U(10),XXA(10),XXB(10)
      DIMENSION ARRAY(12)
      DIMENSION BU(10,100),WU(10,100)
C
      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2
      COMMON GAMMA,FSM,FSP,FST,SW
      COMMON XX1,XX3U,XXA,XXB
C
      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(
15),ZMU1),
2 (XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),
3 (XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),
4 (XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),
5 (XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),
6 (XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),
7 (XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),
1 ZMU3A)
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),
1 (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),
2 (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),
3 (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),
4 (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),
5 (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),
8 (XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),
1 ZMU3B),
9 (XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),
6 (XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),
1 (XX3(10),NPONT3),(XX5(10),NPONT5)
C
500 FORMAT (///19H ERROR IN CHAIN II.)
510 FORMAT (1P6E15.5)
C
C
20 CCC = 1.
C
950J2000
950J2001
950J2002
950J2003
950J2004
950J2005
950J2006
950J2007
950J2008
950J2009
950J2010
950J2011
950J2012
950J2013
950J2014
950J2015
950J2016
950J2017
950J2018
950J2019
950J2020
950J2021
950J2022
950J2023
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950J2031
950J2032
950J2033
950J2034
950J2035
950J2036
950J2037
950J2038
950J2039

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3C      BACKSPACE 3
        BACKSPACE 4
        READ TAPE 3,BU
        READ TAPE 4,B
        CALL MOVE1 (IB,B)
        XXL = R(1,IR-2)
        YYL = B(2,IR-2)
        YYU = YYL
        XXU = 100.0
        YYL1 = YYL
        XXL1 = 100.0
        REWIND 2
        READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY
        CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM)
        C1 = GAMMA
        SW = (BU(2,1)-B(2,1))/20.
        SWL = SW
        FSMS = FSM**2
        XX1U(3) = (1.+(GAMMA-1.)/2.*FSMS)**(-GAMMA/(GAMMA-1.))
        XX1U(4) = 0.0
        XX1U(5) = ATANF(SQRTF(1./(FSMS-1.)))
        XX1U(6) = 1.0
C
301     IBU = 2
3010    IWU = 1
        SW = SWL/2.0
        IF (IBU(7,IBU-1)) 303,303,302
302     CALL DMOVE (WU(1,1),BU(1,IBU))
        GO TO 40
303     IF (BU(7,IBU)) 999,305,304
304     CALL BODYPT (-1.,BU(1,IBU-1),BU(1,IBU+1),WU(1,IWU),C1,M1)
        IRU = IBU+1
        CALL DMOVE (XX1,BU(1,IBU+1))
        IF (NPT1-12345) 32,40,32
305     CONTINUE
        CALL BODYPT (-1.,BU(1,IBU-1),BU(1,IBU),WU(1,IWU),C1,M1)
        M1 = M1
        GO TO (31,999),M1
C
31     WU(7,1) = BU(7,1)
32     IWU = IWU+1

```

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950J2040
950J2041
950J2042
950J2043
950J2044
950J2045
950J2046
950J2047
950J2048
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950J2051
950J2052
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950J2070
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950J2073
950J2074
950J2075
950J2076
950J2077
950J2078
950J2079
950J2080

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33      IBU = IBU+1
C
35      IF (BU(7,IBU)) 999,35,33
      CALL FDPT (BU(1,IBU),WU(1,IWU-1),WU(1,IWU),C1,M1)
      CALL DMOVE (XX1,BU(1,IBU+1))
      WU(7,IWU) = 0.0
      IF (NPT1-12345) 32,40,32
C
40      CONTINUE
      XX1U(1) = BU(1,IBU-1)
      XX1U(2) = BU(2,IBU-1)
      CALL SHOCK (2,M1,-1,XXA,XXB,XX1U,BU(1,IBU-1),WU(1,IWU),
1      XX3U,XX3,XX5,C1,SW,FSM)
      M1 = M1
      GO TO (50,999,999,999,45),M1
45      IF (SWL/SW-4.0) 47,145,145
145      IF (IWU-1) 999,47,55
47      SW = SW/2.0
      GO TO 40
C
50      NPT3 = 2
      XXU1 = XXU
      YYU1 = YYU
      XXU = XX3(1)
      YYU = XX3(2)
      CALL DMOVE (WU(1,IWU+1),XX3)
      CALL FDPT (WU(1,IWU+1),WU(1,IWU),WU(1,IWU+2),C1,M1)
      IWU = IWU+2
      CALL DMOVE (BU(1,IBU-1),WU(1,IWU-1))
      GO TO 40
C
55      NPT3 = 12345
      IF (WU(7,IWU-1)) 3011,3012,3011
3012      SW = SW/2.0
      IF (SWL/SW-10.0) 40,999,999
3011      CALL DMOVE (WU(1,IWU+1),XX3)
      IF (WU(7,IWU-3)) 3100,3100,3080
3080      N1 = IWU-5
3085      IF (N1) 3100,3100,3086
3086      IF (WU(7,N1)) 3090,3090,3088
3088      N1 = N1-2

```

950J2081  
950J2082  
950J2083  
950J2084  
950J2086  
950J2087  
950J2088  
950J2089  
950J2090  
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950J2108  
950J2109  
950J2110  
950J2111  
950J2112  
950J2113  
950J2114  
950J2115  
950J2116  
950J2117  
950J2118  
950J2119  
950J2120  
950J2120  
950J2121

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3090 GO TO 3085
      N1 = N1+2
      XXU1 = WU(1,N1)
      YYU1 = WU(2,N1)
3100 CONTINUE
      CALL STORE (BU,WU,3,M,ARRAY)
      GO TO 123
C
C      CALCULATE CHARACTERISTIC TO LOWER BODY
C
60      IB = 2
3015 IW = 1
      SW = SWL
      IF (B(7,IB-1)) 602,602,601
601      CALL DMOVE (W(1,1),B(1,IB))
      GO TO 70
602      IF (B(7,IB)) 999,605,604
604      CALL BODYPT (1,B(1,IB-1),B(1,IB+1),W(1,IW),Cl,M1)
      IB = IB+1
      CALL DMOVE (XX1,B(1,IB+1))
      IF (NPT1-12345) 62,70,62
605      CONTINUE
      CALL BODYPT (1,B(1,IB-1),B(1,IB),W(1,IW),Cl,M1)
      M1 = M1
      GO TO (61,999),M1
C
61      W(7,1) = B(7,1)
62      IW = IW+1
63      IB = IB+1
C
      IF (B(7,IB)) 999,65,63
65      CALL FDPT (W(1,IW-1),B(1,IB),W(1,IW),Cl,M1)
      CALL DMOVE (XX1,B(1,IB+1))
      W(7,IW) = 0.0
      IF (NPT1-12345) 62,70,62
C
70      CONTINUE
      XX1U(1) = B(1,IB-1)
      XX1U(2) = B(2,IB-1)
      CALL SHOCK (2,M1,1,XXA,XXB,XX1U,B(1,IB-1),W(1,IW),XX3U,XX3,XX5,
1      Cl,SW,FSM)

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950J2122
950J2123
950J2124
950J2125
950J2126
950J2127
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950J2129
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950J2150
950J2151
950J2152
950J2153
950J2155
950J2156
950J2157
950J2158
950J2159
950J2160
950J2161
950J2162
950J2163

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      M1 = M1
      GO TO 780,999,999,999,75),M1
75  IF (SWL/SW-2.0) 77,185,185
185 IF (IW-1) 999,77,85
77  SW = SW/2.0
      GO TO 70
C
      NPT3 = 1
      XXL1 = XXL
      YYL1 = YYL
      XXL = XX3(1)
      YYL = XX3(2)
      CALL DMOVE (W(1,IW+1),XX3)
      CALL FDPT (W(1,IW),W(1,IW+1),W(1,IW+2),C1,M1)
      CALL DMOVE (B(1,IB-1),W(1,IW+1))
      IW = IW+2
      GO TO 70
C
      NPT3 = 12345
      IF (W(7,IW-1)) 3013,3014,3013
3014 SW = SW/2.0
      IF (SWL/SW-10.0) 70,999,999
3013 CALL DMOVE (W(1,IW+1),XX3)
      IF (W(7,IW-3)) 3070,3070,3030
3030 N1 = IW-5
3040 IF (N1) 3070,3070,3045
3045 IF (W(7,N1)) 3060,3060,3050
3050 N1 = N1-2
      GO TO 3040
3060 N1 = N1+2
      XXL1 = W(1,N1)
      YYL1 = W(2,N1)
3070 CONTINUE
      CALL STORE (B,W,4,M,ARRAY)
C
123 CONTINUE
      CALL XY (XXU1,YYU1,XXU,YYU,XXL1,YYL1,XXL,YYL,X,Y)
      IF (X-XXU) 121,122,122
121 IF (X-XXL) 120,122,122
122 CONTINUE
      IF (XXL-XXU) 60,60,301

```

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950J2164
950J2165
950J2166
950J2167
950J2168
950J2169
950J2170
950J2171
950J2172
950J2173
950J2174
950J2175
950J2176
950J2177
950J2178
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950J2192
950J2193
950J2194
950J2195
950J2196
950J2197
950J2198
950J2199
950J2200
950J2201
950J2202
950J2203

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C 120 CALL CHAIN (3*8)
    999 WRITE OUTPUT TAPE 6*500
      CALL DUMP
C      END

```

```

950J2204
950J2205
950J2206
950J2207
950J2208

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C      TURNING VANES - HEAD-ON COLLISION OF SHOCK WAVES IN
C      A UNIFORM SUPERSONIC FLOW FIELD.
*      LABEL
950J3
C
C      950J3
C      950J3002
C      950J3003
C      950J3004
C      950J3005
C      950J3006
C      950J3007
C      950J3008
C      950J3009
C      950J3010
C      950J3011
C      950J3012
C      950J3013
C      950J3014
C      950J3015
C      950J3016
C      950J3017
C      950J3018
C      950J3019
C      950J3020
C      950J3021
C      950J3022
C      950J3023
C      950J3024
C      950J3025
C      950J3026
C      950J3027
C      950J3028
C      950J3029
C      950J3030
C      950J3031
C      950J3032
C      950J3033
C      950J3034
C      950J3035
C      950J3036
C      950J3037

      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),
      XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)
      DIMENSION AC1(6,20),AC2(6,20)
      DIMENSION XX1U(10),XX3U(10),XXA(10),XXB(10)
      DIMENSION ARRAY(12)
      DIMENSION BU(10,100),WU(10,100)
      DIMENSION XXX1(100),YY1(100),XXX2(100),YY2(100)

      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2
      COMMON GAMMA,FSM,FSP,FST,SW
      COMMON XX1,XX3U,XXA,XXB
      COMMON BU,WU

      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(
      15),ZMU1),
      2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),
      3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),
      4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),
      5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),
      6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),
      7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),
      1 ZMU3A)
      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),
      1 (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),
      2 (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),
      3 (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),
      4 (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),
      5 (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),
      8 (XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),
      1 ZMU3B),
      9 (XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),
      6 (XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)
      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),
      1 (XX3(10),NPONT3),(XX5(10),NPONT5)

```

```

500 FORMAT (/1P6E15.5/3X1P6E15.5/6X1P6E15.5)
510 FORMAT (1P6E14.5,15,1PE14.5)
520 FORMAT (1P2E15.5)
C
REWIND 2
READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY
CALL PAGE2 (0,ARRAY)
BACKSPACE 4
BACKSPACE 3
C1 = GAMMA
C2 = 1./(1.-C1)
C3 = C1/(C1-1.0)
C4 = 2.*C1/(C1+1.)
C6 = 2./(C1+1.0)
C7 = (C1-1.0)/C1
C10 = (C1-1.0)/2.0
C11 = (C1-1.0)/(2.*C1)
C12 = 2./(1.-C1)
C
TAPE 3 CONTAINS FIELD ABOUT UPPER BODY, AND
C
C TAPE 4 CONTAINS DATA ABOUT LOWER BODY.
C
READ TAPE 3,W
READ TAPE 4,B
ZMU1U = ASINF(1./FSM)
PIU = (1.+C10*FSM**2)**(-C3)
TH1U = 0.0
RIU = 1.0
C
CALL MOVE1 (IB,W)
XLAST1 = W(1,IB-2)
CALL MOVE1 (IB,B)
XLAST2 = B(1,IB-2)
END FILE 3
END FILE 4
REWIND 3
REWIND 4
N1 = 0
N2 = 0
C
READ TAPE 3,WU

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```

950J3038
950J3039
950J3040
950J3041
950J3042
950J3043
950J3044
950J3045
950J3046
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950J3068
950J3069
950J3070
950J3071
950J3072
950J3073
950J3074
950J3075
950J3076
950J3077
950J3078

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170 READ TAPE 3,WU
    READ TAPE 4,W
    READ TAPE 4,W
    DO 200 I=1,100
    READ TAPE 3,WU
    DO 180 J=1,100
    CALL DMOVE (XX1,WU(1,J))
    IF (NPT1 -2) 180,170,200
    N1 = N1+1
    XXX1(N1) = WU(1,J)
    YY1(N1) = WU(2,J)
    IF (XXX1(N1)-XLAST1) 180,210,180
    CONTINUE
    CONTINUE
    C
210 NPT1 = 1
    DO 230 I=1,100
    READ TAPE 4,W
    DO 220 J=1,100
    CALL DMOVE (XX1,W(1,J))
    IF (NPT1-1) 220,212,230
    N2 = N2+1
    XX2(N2) = W(1,J)
    YY2(N2) = W(2,J)
    IF (XX2(N2)-XLAST2) 220,215,220
    CONTINUE
    CONTINUE
    215 IF (N1-100) 240,240,999
    240 IF (N2-100) 250,250,999
    250 CONTINUE
    C
    CALL MEET (XXX1,YY1,N1,XXX2,YY2,N2,X,Y,DY1,DY2)
    C
    W1 = ATANF(DY1)
    W2 = ATANF(DY2)
    XX5(1) = X
    XX5(2) = Y
    XX5(3) = PIU
    XX5(4) = O.O
    XX5(5) = ZMU1U
    XX5(6) = 1.O

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950J3079
950J3080
950J3081
950J3082
950J3083
950J3084
950J3085
950J3086
950J3087
950J3088
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950J3090
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950J3100
950J3101
950J3102
950J3103
950J3104
950J3105
950J3106
950J3107
950J3108
950J3109
950J3110
950J3111
950J3112
950J3113
950J3114
950J3115
950J3116
950J3117
950J3118
950J3119

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CALL OBLSHK (XX5,W1,XX1,GAMMA)	950J3120
CALL OBLSHK (XX5,W2,XX2,GAMMA)	950J3121
BACKSPACE 3	950J3122
BACKSPACE 3	950J3123
READ TAPE 3,WU	950J3124
CALL MOVE1 (IW,WU)	950J3125
IF (WU(1,IW-2)-X) 310,310,300	950J3126
310 READ TAPE 3,WU	950J3127
C	950J3128
320 BACKSPACE 4	950J3129
BACKSPACE 4	950J3130
READ TAPE 4,W	950J3131
CALL MOVE1 (IW,W)	950J3132
IF (W(1,IW-2)-X) 330,330,320	950J3133
330 READ TAPE 4,W	950J3134
CALL DMOVE (XX3,XX1)	950J3135
CALL DMOVE (XX5,XX2)	950J3136
C	950J3137
NPT3 = 2	950J3138
NPT5 = 1	950J3139
CALL DMOVE (BU(1,1),XX3)	950J3140
CALL DMOVE (B(1,1),XX5)	950J3141
C	950J3142
STH = TH1U+TH3+TH5	950J3143
IF (STH) 20,10,20	950J3144
DSTH = .1	950J3145
GO TO 30	950J3146
DSTH = .1*ARSF(STH)	950J3147
DO 120 JJ=1,10	950J3148
STH = STH-DSTH	950J3149
DSTH = DSTH/4.	950J3150
DO 100 I=1,10	950J3151
M1 = I	950J3152
CALL SHK1 (1.0,STH,XX3,XX1,GAMMA,M2)	950J3153
IF (M2-1) 999,32,999	950J3154
C	950J3155
32 CALL SHK1 (-1.0,STH,XX5,XX2,GAMMA,M2)	950J3156
IF (M2-1) 999,90,999	950J3157
C	950J3158
90 CALL CONV (P1,P2,STH,DSTH,M1)	950J3159
100 CONTINUE	950J3160

C	110	CALL SHK1 (1.0,STH,XX3,XX1,GAMMA,M2)	950J3161
		IF (M2-1) 999,35,999	950J3162
	35	CALL SHK1 (-1.0,STH,XX5,XX2,GAMMA,M2)	950J3163
		IF (M2-1) 999,38,999	950J3164
	38	NPT1 = -21	950J3165
		NPT2 = -11	950J3166
		IF (ABSF(P1-P2)-.001*P1) 130,130,120	950J3167
C	120	DSTH = DSTH*2.	950J3168
	130	CALL DMOVE (BU(1,2),XX1)	950J3169
		W2 = -W2	950J3170
		CALL DMOVE (B(1,2),XX2)	950J3171
C			950J3172
		CALL SHKCAL (XLAST1,XLAST2)	950J3173
C			950J3174
		CALL CHAIN (4,8)	950J3175
	999	CALL DUMP	950J3176
		END	950J3177
			950J3178



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9011 W1 = ABSF{XX1(8)}
      X3A = XXA(1)
      Y3A = XXA(2)
      P3A = XXA(3)
      TH3A = XXA(4)
      ZMU3A = XXA(5)
      R3A = XXA(6)
      X3B = XXB(1)
      Y3B = XXB(2)
      P3B = XXB(3)
      TH3B = XXB(4)
      ZMU3B = XXB(5)
      R3B = XXB(6)
      XA = X3A
      XB = X3B
762 ZM3A = 1./SINF(ZMU3A)
      ZM3B = 1. / SINF(ZMU3B)
C
783 NFLAG = XABSF(N)
      W3 = W1
737 SLP1 = (Y3B-Y3A)/(X3B-X3A)
      T61 = P3B - P3A
      T62 = TH3B - TH3A
      T63 = ZMU3B - ZMU3A
      T64 = R3B - R3A
700 RR2 = 0.5
      P3LS = 1000.
      KTR = 0
      RRI=0.5
      SH1 = T62/2.
      SH2 = (TH1U+TH3A)/2.
      SH3 = 1./SLP1
      SH4 = (Y3A-Y1)/(Y3B-Y3A)
      SH5 = (X3A-X1)/(X3B-X3A)
701 SH6 = (AA*(W3+W1) + TH1U + TH3A)/2.
      DO 771 I=1,20
      SH8 = SH6+RRI*SH1
      SH9 = SINF(SH8)
      SH10= COSF(SH8)
      SH11= SH9/SH10

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950JC076
950JC077
950JC078

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SH12= RR1+SH4-(RR1+SH5)*SH3*SH11
SH13= 1.-SH3*(SH11+SH1*(RR1+SH5)/(SH10)**2)
IF (ABSF(SH13) - .00000001) 773,773,772
772 DRR1 = SH12 / SH13
RR1 = RR1 - DRR1
IF (ABSF(DRR1) - MAX1F(ABSF(RR1 * .000001) * .000001)) 773,773,771
771 CONTINUE
773 X3 = X3A +RR1*(X3B-X3A)
Y3 = Y3A +RR1*(Y3B-Y3A)
P3U = P3A +RR1*T61
TH3U =TH3A + RR1*T62
ZMU3U = ZMU3A + T83* RR1
ZM3U =ZM3A + RR1*T63
R3U = R3A +RR1*T64
T29 = SIN(2.*W3)
T31 = SIN(W3)**2
T32 = ZM3U**2
DEL3=ATANF((T32*T29-2.*COSF(W3)/SINF(W3))/(T32*(C1+COSF(2.*W3))+2.
1))
T28 = SIN(DEL3)**2
TH3 = TH3U +AA*DEL3
ERASB = C4*(T32*T31-C11)
P3= P3U*ERASB
R3= ((T32*T31)/(C5*((T32*T31)-C12)))*C3*ERASB**C2*R3U
T30 = P3/R3
IF (T30) 651,651,703
651 M1 = 2
WRITE OUTPUT TAPE 6,22
GO TO 100
703 T30 = C12*(1.-(T30)**(-C7))-1.
IF (T30-.04) 651,651,705
705 ZMU3 = ATANF(SORTF(1.0/T30))
778 IF (ABSF(P3 - P3LS) - .000001) 780,780, 715
715 P3LS=P3
IF (KTR-100) 1019,1019,780
1019 KTR = KTR+1
776 X2=X3
Y2=Y3
P2=P3
TH2=TH3
ZMU2=ZMU3
950JCG79
950JC080
950JC081
950JC082
950JC083
950JC084
950JC085
950JC086
950JC087
950JC088
950JC089
950JC090
950JC091
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950JC148  
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950JC150  
950JC151  
950JC152  
950JC153  
950JC154  
950JC155  
950JC156  
950JC157  
950JC158  
950JC159  
950JC160

R2=R3  
NPT2=NPT3  
XX2(1) = X2  
XX2(2) = Y2  
XX2(3) = P2  
XX2(4) = TH2  
XX2(5) = ZMU2  
XX2(6) = R2  
CALL DMOVE (XX3,XX5)  
CALL SLPSTM (AA,XX1,XX2,XX3,C1)  
10 X5 = XX3(1)  
Y5 = XX3(2)  
P5 = XX3(3)  
TH5 = XX3(4)  
ZMU5 = XX3(5)  
R5 = XX3(6)  
CALL DMOVE (XX5,XX3)  
X3=X2  
Y3=Y2  
P3=P2  
TH3=TH2  
ZMU3=ZMU2  
R3=R2  
X2=X5  
Y2=Y5  
P2=P5  
TH2=TH5  
ZMU2=ZMU5  
740 R2=R5  
T42 = Y1 -Y3  
T36 = X2 -X1  
T37 = Y2 -Y1  
T39 = (TH2 +AA\*ZMU2)/2.  
T40 = (TH1 +AA\*ZMU1)/2.  
T38 = P2- P1  
T35 = TH2 -TH1  
T33 = ZMU2 -ZMU1  
T45 = T39 -T40  
T46 = T37/T36  
T43 = X1 -X3  
T47 = T42/T36

```

T48 = T43/T36
T50 = (TH3 + AA*ZMU3)/2.
T49 = T40 + T50
RR2 = .5
706 DO 750 I=1,20
T51 = RR2*T45 + T49
T52 = SIN(T51)
T53 = COS(T51)
T54 = T52/T53
FR = T47 + RR2*T46 - (RR2 + T48)*T54
FPR = T46 - T54 - (RR2 + T48)*T45/T53**2
IF (ABS(FPR) - .00000001) 711,711, 751
751 DRR = FR/FPR
RR2 = RR2 - DRR
CONTINUE
708
725 IF (ABS(DRR) - MAX1F(.00001 * ABSF(RR2) , .00001)) 711, 711, 750
750 CONTINUE
711 IF (ABS(RR2-.5)-.5) 747,747,111
111 IF (NPT2) 60,61,61
60 IF (RR2 + .01) 1160,747,747
1160 WRITE OUTPUT TAPE 6,23
500 M1 = 3
GO TO 100
C
61 IF (RR2) 666,661,661
666 IF (RR2 + .001) 670,747,747
670 WRITE OUTPUT TAPE 6,25,X1,Y1,P1,TH1,ZMU1,W1
WRITE OUTPUT TAPE 6,25,X2,Y2,P2,TH2,ZMU2,W2
WRITE OUTPUT TAPE 6,25,X3,Y3,P3,TH3,ZMU3,W3
WRITE OUTPUT TAPE 6,25,X4,Y4,P4,TH4,ZMU4,W4
WRITE OUTPUT TAPE 6,25,RR2,DRR,DPDW,DTHDW,DW3,T30
WRITE OUTPUT TAPE 6,25,X3A,Y3A,X3B,Y3B,
GO TO 500
661 M1 = 5
C
C THE NEXT POINT MUST BE USED AS POINT 2.
C
GO TO 100
C
747 X4 = X1 + RR2*T36
Y4 = Y1 + RR2*T37
950JC161
950JC162
950JC163
950JC164
950JC165
950JC166
950JC167
950JC168
950JC169
950JC170
950JC171
950JC172
950JC173
950JC174
950JC175
950JC176
950JC177
950JC178
950JC179
950JC180
950JC181
950JC182
950JC183
950JC184
950JC185
950JC186
950JC187
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950JC191
950JC192
950JC193
950JC194
950JC195
950JC196
950JC197
950JC198
950JC199
950JC200
950JC201

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P4 = P1 +RR2*T38
TH4 =TH1 +RR2*T35
ZMU4 =ZMU1+RR2*T33
DPDW = P3U*C4*T32*T29
DTHDW = (C1+1.0)*T28*T31*T32**2/(T32*T31-1.0)**2 - SIN(2.0*DEL3)/950JC206
1T29
T13 =(TH4 +TH3)/2.0
T60 = (TH4 +AA*ZMU4)/2.
T11 =(P4 +P3)/2.0
T12 =(ZMU4 +ZMU3)/2.0
T34 = (Y4 +Y3)/2.0
DW3 = -((P3-P4)/(C1*T11)+A*(TH3-TH4)/((COSF(T12))*(SINF(T12))))
774 W3=W3+DW3/(DPDW/(C1*T11)+DTHDW/(SINF(T12)/COSF(T12)))
GO TO 701
780 M1 = 1
765 IF (RR1) 763,763,1900
1900 IF (RR1-1.0) 100,100,1904
C
763 M1 = 6
C
C NEW 3A AND 3B POINTS UPSTREAM MUST BE USED.
C
GO TO 100
C
1904 M1 = 7
C
C NEW 3A AND 3B POINTS DOWNSTREAM MUST BE USED.
C
C
100 XX3U(1) = X3
XX3(1) = X3
XX3U(2) = Y3
XX3(2) = Y3
XX3U(3) = P3U
XX3U(4) = TH3U
XX3U(5) = ZMU3U
XX3U(6) = R3U
XX3(3) = P3
XX3(4) = TH3
XX3(5) = ZMU3
XX3(6) = R3
XX3(8) = SIGNF(W3,XX1(8))
950JC202
950JC203
950JC204
950JC205
950JC206
950JC207
950JC208
950JC209
950JC210
950JC211
950JC212
950JC213
950JC214
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950JC227
950JC228
950JC229
950JC230
950JC231
950JC232
950JC233
950JC234
950JC235
950JC236
950JC237
950JC238
950JC239
950JC240
950JC241
950JC242

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950JC243

RETURN  
END

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SUBROUTINE SHKCAL (XLASTU,XLASTL)
*
* 950JB
* LABEL
*
C
  DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),
    XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)
  DIMENSION AC1(6,20),AC2(6,20)
  DIMENSION XX1U(10),XX3U(10),XXA(10),XXB(10)
  DIMENSION ARRAY(12)
  DIMENSION BU(10,100),WU(10,100)
  DIMENSION TH(20),PPD(20),PPU(20)
  DIMENSION DATA(10,8)

C
  COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2
  COMMON GAMMA,FSM,FSP,FST,SW
  COMMON XX1,XX3U,XXA,XXB
  COMMON BU,WU

C
  EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(
    5),ZMU1),
    2(XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),
    3(XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),
    4(XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),
    5(XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),
    6(XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),
    7(XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),
    1 ZMU3A)
  EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),
    1 (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),
    2 (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),
    3 (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),
    4 (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),
    5 (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),
    8(XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),
    1 ZMU3B),
    9(XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),
    6(XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)
  EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),
    1 (XX3(10),NPONT3),(XX5(10),NPONT5)
  400 FORMAT (1P7E14.5)

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C      PPUDF(XY1,XY2,XY3,XY4,XY5) = (XY1-XY3)/(XY2-XY3)*(XY4-XY5)+XY5
      C1 = GAMMA
      DO 15 I=2,100
      II = I+1
      IF (W(7,I)) 5,5,15
      IF (W(7,II)) 7,7,6
      II = II+1
      OMEGA = -ABSF(B(8,2))
      CALL XY (B(1,1),B(2,1),O,OMEGA,W(1,I),W(2,I),W(1,II),W(2,II),X,Y)
      RR = (X-W(1,I))/(W(1,II)-W(1,I))
      IF (RR) 999,10,10
      IF (RR-1.0) 17,17,15
      CONTINUE
      10
      15
      C      DSL = SORTF((B(1,1)-X)**2+(B(2,1)-Y)**2)
      DO 30 J=2,100
      JJ = J+1
      IF (WU(7,J)) 20,20,30
      IF (WU(7,JJ)) 25,25,22
      JJ = JJ+1
      CALL XY (BU(1,1),BU(2,1),O,O,BU(8,2),WU(1,J),WU(2,J),
      1 WU(1,JJ),WU(2,JJ),X,Y)
      RR = (X-WU(1,J))/(WU(1,JJ)-WU(1,J))
      IF (RR) 999,27,27
      IF (RR-1.0) 35,35,30
      CONTINUE
      27
      30
      C      DSU = SORTF((B(1,1)-X)**2+(B(2,1)-Y)**2)
      IF (DSU/2.-DSL) 40,40,50
      IF (DSL/2.-DSU) 70,70,60
      CALL MOVE1 (IW,W)
      IF (W(1,IW-2)-XLASTL) 55,70,55
      READ TAPE 4,W
      GO TO 2
      CALL MOVE1 (IWU,WU)
      IF (WU(1,IWU-2)-XLASTU) 65,70,65
      READ TAPE 3,WU
      GO TO 2
      IK = I
      IIK = II

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          JK = J
          JJK = JJ
C
          DDTH = .04
          L = 9
          CALL DMOVE (DATA(1,3),BU(1,2))
          CALL DMOVE (DATA(1,6),B(1,2))
          DO 100 IJ=1,5
          DTH = DDTH/4.
          DATA(4,3) = DATA(4,3)-DDTH
          DATA(4,6) = DATA(4,3)
          CONTINUE
901      DO 90 I=1,L
          CALL DMOVE (XXA,WU(1,JK))
          CALL DMOVE (XXB,WU(1,JJK))
          CALL DMOVE (XX1U,BU(1,1))
          CALL DMOVE (XX1,BU(1,2))
          CALL DMOVE (XX5,DATA(1,3))
          CALL SHOCK5 (M1,1.0,XXA,XXB,XX1U,XX1,XX3U,XX3,XX5,C1)
C
          M1 = M1
          GO TO (220,999,999,999,999,200,210),M1
          JJK = JK
200      JK = JK-1
205      CALL DMOVE (XX1,WU(1,JK))
          IF (NPT1-2) 190,205,220
          JK = JJK
210      JJK = JJK+1
215      CALL DMOVE (XX1,WU(1,JJK))
          IF (NPT1-2) 190,215,220
          CALL DMOVE (DATA(1,1),XX3U)
220      CALL DMOVE (DATA(1,2),XX3)
          CALL DMOVE (DATA(1,3),XX5)
C
          CALL DMOVE (XXA,W(1,IK))
225      CALL DMOVE (XXB,W(1,IJK))
          CALL DMOVE (XX1U,B(1,1))
          CALL DMOVE (XX1,B(1,2))
          CALL DMOVE (XX5,DATA(1,6))
C
          CALL SHOCK5 (M1,-1.0,XXA,XXB,XX1U,XX1,XX3U,XX3,XX5,C1)

```

```

230 M1 = M1
235 GC TO (250,999,999,999,999,999,999,230,240),M1
240 IIK = IK
245 IK = IK-1
C CALL DMOVE (XX1,W(1,IK))
IF (NPT1-1) 225,235,250
C
240 IK = IIK
245 IIK = IIK+1
C CALL DMOVE (XX1,W(1,IIK))
IF (NPT1-1) 225,245,250
C
250 CALL DMOVE (DATA(1,4),XX3U)
CALL DMOVE (DATA(1,5),XX3)
CALL DMOVE (DATA(1,6),XX5)
TH(1) = XX5(4)
DATA (4,3) = XX5(4)+DTH
DATA (4,6) = DATA(4,3)
IF (DATA(1,6)-DATA(1,3)) 80,80,85
C
85 PPD(1) = PPUDF(DATA(1,3),DATA(1,6),B(1,2),DATA(3,6),B(3,2))
PPU(1) = DATA(3,3)
GO TO 90
80 PPD(1) = DATA(3,6)
PPU(1) = PPUDF(DATA(1,6),DATA(1,3),BU(1,2),DATA(3,3),BU(3,2))
C
90 CONTINUE
IF (L-9) 96,94,96
C
94 L = 1
C
CALL MEET (TH,PPU,9,TH,PPD,9,DATA(4,3),DATA(3,3),DY1,DY2)
DATA(4,6) = DATA(4,3)
DTH = 0.0
DATA(3,6) = DATA(3,3)
GO TO 901
C
96 L = 9
DDTH = DDTH/2.
IF (ABSF(PPD(1)-PPU(1)) -.0001*B(3,2)) 110,110,100
100 CONTINUE

```

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950JB120
950JB121
950JB122
950JB123
950JB124
950JB125
950JB126
950JB127
950JB128
950JB129
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950JB131
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950JB133
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950JB143
950JB144
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950JB146
950JB147
950JB148
950JB149
950JB150
950JB151
950JB152
950JB153
950JB154
950JB155
950JB156
950JB157
950JB158
950JB159
950JB160

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```

110 98NTINYE
    IB = JK+4
    CALL DMOVE (W(1,IB-3),B(1,1))
    CALL DMOVE (W(1,IB-2),B(1,2))
    CALL DMOVE (W(1,IB-1),DATA(1,4))
    CALL DMOVE (W(1,IB),DATA(1,5))
    W(7,IB) = ABSF(W(7,IB))
    CALL DMOVE (W(1,IB+1),DATA(1,6))
    NPT1 = 12345
    CALL DMOVE (W(1,IB+2),XX1)
    CALL DMOVE (WU(1,IBU-3),BU(1,1))
    CALL DMOVE (WU(1,IBU-2),BU(1,2))
    CALL DMOVE (WU(1,IBU-1),DATA(1,1))
    CALL DMOVE (WU(1,IBU),DATA(1,2))
    WU(7,IBU) = ABSF(WU(7,IBU))
    CALL DMOVE (WU(1,IBU+1),DATA(1,3))
    NPT1 = 12345
    CALL DMOVE (WU(1,IBU+2),XX1)
    BACKSPACE 3
    BACKSPACE 4
    CALL STORE (BU,WU,3,M,ARRAY)
    CALL STORE (B,W,4,M,ARRAY)
    RETURN
999 CALL DUMP
    END

```

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950JB161
950JB162
950JB163
950JB164
950JB165
950JB166
950JB167
950JB168
950JB169
950JB170
950JB171
950JB172
950JB173
950JB174
950JB175
950JB176
950JB177
950JB178
950JB179
950JB180
950JB181
950JB182
950JB183
950JB184
950JB185

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```

C      MAIN PROGRAM FOURTH CHAIN - TURNING VANE
*      LABEL
950J4
C      DIMENSION B(10,100),W(10,100),XX1(10),XX2(10),XX3(10),XX4(10),
1      XX5(10),XX7(10),XX3A(10),XX3B(10),M(10)
C      DIMENSION AC1(6,20),AC2(6,20)
C      DIMENSION XX1U(10),XX3U(10),XXA(10),XXB(10)
C      DIMENSION ARRAY(12)
C      DIMENSION DATA(10,8)
C      DIMENSION BU(10,100),WU(10,100)
C      COMMON B,W,XX1,XX2,XX3,XX4,XX5,XX7,XX3A,XX3B,M,AC1,AC2
C      COMMON GAMMA,FSM,FSP,FST,SW
C      COMMON XX1,XX3U,XXA,XXB
C      EQUIVALENCE (XX1(1),X1),(XX1(2),Y1),(XX1(3),P1),(XX1(4),TH1),(XX1(
15),ZMU1),
2 (XX2(1),X2),(XX2(2),Y2),(XX2(3),P2),(XX2(4),TH2),(XX2(5),ZMU2),
3 (XX3(1),X3),(XX3(2),Y3),(XX3(3),P3),(XX3(4),TH3),(XX3(5),ZMU3),
4 (XX4(1),X4),(XX4(2),Y4),(XX4(3),P4),(XX4(4),TH4),(XX4(5),ZMU4),
5 (XX5(1),X5),(XX5(2),Y5),(XX5(3),P5),(XX5(4),TH5),(XX5(5),ZMU5),
6 (XX7(1),X7),(XX7(2),Y7),(XX7(3),P7),(XX7(4),TH7),(XX7(5),ZMU7),
7 (XX3A(1),X3A),(XX3A(2),Y3A),(XX3A(3),P3A),(XX3A(4),TH3A),(XX3A(5),
1 ZMU3A)
C      EQUIVALENCE (XX3(6),R3),(XX3(7),NPT3),(XX3(8),W3),(XX3(9),ZM3),
1 (XX4(6),R4),(XX4(7),NPT4),(XX4(8),W4),(XX4(9),ZM4),
2 (XX5(6),R5),(XX5(7),NPT5),(XX5(8),W5),(XX5(9),ZM5),
3 (XX7(6),R7),(XX7(7),NPT7),(XX7(8),W7),(XX7(9),ZM7),
4 (XX3A(6),R3A),(XX3A(7),NPT3A),(XX3A(8),W3A),(XX3A(9),ZM3A),
5 (XX3B(6),R3B),(XX3B(7),NPT3B),(XX3B(8),W3B),(XX3B(9),ZM3B),
8 (XX3B(1),X3B),(XX3B(2),Y3B),(XX3B(3),P3B),(XX3B(4),TH3B),(XX3B(5),
1 ZMU3B),
9 (XX1(6),R1),(XX1(7),NPT1),(XX1(8),W1),(XX1(9),ZM1),
6 (XX2(6),R2),(XX2(7),NPT2),(XX2(8),W2),(XX2(9),ZM2)
C      EQUIVALENCE (XX1(10),NPONT1),(XX2(10),NPONT2),
1 (XX3(10),NPONT3),(XX5(10),NPONT5)
C      500 FORMAT (15H ERROR IN SHOCK)
510 FORMAT (1P6E15.5)
950J4000
950J4
950J4001
950J4002
950J4003
950J4004
950J4005
950J4006
950J4007
950J4008
950J4009
950J4010
950J4011
950J4012
950J4013
950J4014
950J4015
950J4016
950J4017
950J4018
950J4019
950J4020
950J4021
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950J4037

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950J4038
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950J4067
950J4068
950J4069
950J4070
950J4071
950J4072
950J4073
950J4074
950J4075
950J4076
950J4077
950J4078

REWIND 9
BACKSPACE 3
BACKSPACE 4
READ TAPE 3,BU
READ TAPE 4,B
DO 10 I=1,100
NPONT3 = I
B(10,I) = XX3(10)
BU(10,I) = XX3(10)
CONTINUE
10 REWIND 2
READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY
CALL PAGE2 (0,ARRAY)
CALL LOCATE (-1,T,ITT,DUM,DUM,DUM,DUM,DUM)
C1 = GAMMA
CALL MOVE1 (IBU,BU)
XXU = BU(1,IBU-1)
CALL MOVE1 (IB,B)
XXL = B(1,IB-1)
IF (XXU-XXL) 25,25,20
20 BACKSPACE 3
DO 299 I=1,100
DO 299 J=1,10
299 WU(J,I) = BU(J,I)
IWU = IBU-2
IF (WU(7,IBU-4)) 21,999,999
21 IBU = IBU-4
CALL DMOVE (BU(1,IBU),WU(1,IBU))
GO TO 80
25 BACKSPACE 4
DO 259 I=1,100
DO 259 J=1,10
259 W(J,I) = B(J,I)
IW = IB-2
IF (W(7,IB-4)) 26,999,999
26 IB = IB-4
CALL DMOVE (B(1,IB),W(1,IB))
30 CALL CHLIN4 (BU,WU,C1,1,0,IBU,IWU,M1,FSM)
M1 = M1
950J4079

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170 GO TO (170,175,999),M1
CONTINUE
34 CALL XY (WU(1,IWU-1),WU(2,IWU-1),WU(1,IWU),WU(2,IWU),BU(1,IBU),
C 1 BU(2,IBU),0.0,BU(4,IBU),XXU,YYU)
35 IF (XXU-XXL) 35,35,75
CALL CONV4 (BU(1,IBU),WU(1,IWU),B(1,IB),W(1,IW),WU(1,IWU+1),XX5,
C 1 C1,M1)
XXU = WU(1,IWU+1)
YYU = WU(2,IWU+1)
XX3(10) = BU(10,IBU)
NPONT3 = NPONT3+1
WU(10,IWU+1) = XX3(10)
NPT1 = 12345
WU(7,IWU+1) = BU(7,IBU)
CALL DMOVE (WU(1,IWU+2),XX1)
CALL STORE (BU,WU,3,M,ARRAY)
GO TO 30
C
75 CALL CONV4 (BU(1,IBU),WU(1,IWU),B(1,IB),W(1,IW),XX3,W(1,IW+1),
C 1 C1,M1)
XXL = W(1,IW+1)
YYL = W(2,IW+1)
XX3(10) = B(10,IB)
NPONT3 = NPONT3+1
W(10,IW+1) = XX3(10)
NPT1 = 12345
W(7,IW+1) = B(7,IB)
CALL DMOVE (W(1,IW+2),XX1)
CALL STORE (B,W,4,M,ARRAY)
C
80 CALL CHLIN4 (B,W,C1,-1.0,IB,IW,M1,FSM)
M1 = M1
GO TO (180,185,999),M1
180 CONTINUE
85 CALL XY (W(1,IW-1),W(2,IW-1),W(1,IW),W(2,IW),B(1,IB),B(2,IB),
C 1 0.0,B(4,IB),XXL,YYL)
IF (XXL-XXU) 75,75,35
C
175 CONTINUE
CALL CONT5 (WU,-1.0,GAMMA,FSM,N1,M1)

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950J4079  
950J4080  
950J4081  
950J4082  
950J4083  
950J4084  
950J4085  
950J4086  
950J4087  
950J4088  
950J4089  
950J4090  
950J4091  
950J4092  
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950J4097  
950J4098  
950J4099  
950J4100  
950J4101  
950J4102  
950J4103  
950J4104  
950J4105  
950J4106  
950J4107  
950J4108  
950J4109  
950J4110  
950J4111  
950J4112  
950J4113  
950J4114  
950J4115  
950J4116  
950J4117  
950J4118  
950J4119

```

177      NPT1 = 12345
          CALL DMOVE (WU(1,7),XX1)
          CALL STORE (BU,WU,9,M,ARRAY)
          CONTINUE
          CALL CHLIN5 (BU,WU,GAMMA,N1,-1.0,IBU,IW,M1,FSM)
          M1 = M1
          NPT1 = 12345
          CALL DMOVE (WU(1,IW+1),XX1)
          CALL STORE (BU,WU,9,M,ARRAY)
          GO TO (177,888,999),M1

C      185      CONTINUE
          CALL CONT5 (W,1.0,GAMMA,FSM,N2,M1)
          NPT1 = 12345
          CALL DMOVE (W(1,7),XX1)
          CALL STORE (B,W,9,M,ARRAY)

C      187      B(1,100) = 32000.0
          WRITE TAPE 4,B
          BACKSPACE 4
          CONTINUE
          CALL CHLIN5 (B,W,GAMMA,N2,1.0,IB,IW,M1,FSM)
          NPT1 = 12345
          CALL DMOVE (W(1,IW+1),XX1)
          CALL STORE (B,W,9,M,ARRAY)
          M1 = M1
          GO TO (189,999,190),M1

190      CALL CONT6 (DATA,GAMMA)
          CALL DMOVE (W(1,1),DATA(1,1))
          CALL DMOVE (W(1,2),DATA(1,3))
          W(7,2) = W(7,1)
          CALL DMOVE (XX1,DATA(1,2))
          NPT1 = 11
          CALL DMOVE (W(1,3),XX1)
          CALL DMOVE (XX1,DATA(1,4))
          NPT1 = 21
          CALL DMOVE (W(1,4),XX1)
          CALL DMOVE (W(1,5),DATA(1,5))
          W(7,5) = W(7,1)
          NPT1 = 12345
          CALL DMOVE (W(1,6),XX1)

```

```

      B(1,100) = 3333.0
      BU(1,100) = 3333.0
      CALL STORE (B,W,4,M,ARRAY)
      CALL DMOVE (WU(1,IWU+1),XX1)
      BACKSPACE 3
      CALL STORE (BU,WU,3,M,ARRAY)
      CALL CHAIN (5,8)
888  WRITE OUTPUT TAPE 6,500
999  CALL DUMP
      C
      END

```

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950J4161
950J4162
950J4163
950J4164
950J4165
950J4166
950J4167
950J4168
950J4169
950J4170

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```

* 950JF LABEL
SUBROUTINE CHLIN5 (B,W,GAMMA,N,TT,IBB,IWW,MM1,FSM)
950JF000
C 950JF
C 950JF001
C 950JF002
C 950JF003
C 950JF004
C 950JF005
C 950JF006
C 950JF007
C 950JF008
C 950JF009
C 950JF010
C 950JF011
C 950JF012
C 950JF013
C 950JF014
C 950JF015
C 950JF016
C 950JF017
C 950JF018
C 950JF019
C 950JF020
C 950JF021
C 950JF022
C 950JF023
C 950JF024
C 950JF025
C 950JF026
C 950JF027
C 950JF028
C 950JF029
C 950JF030
C 950JF031
C 950JF032
C 950JF033
C 950JF034
C 950JF035
C 950JF036
C 950JF037

T POSITIVE LOWER BODY.
T NEGATIVE UPPER BODY.

DIMENSION B(10,100),W(10,100),XX3U(10),XX3(10),XXA(10),XXB(10)
EQUIVALENCE (XX3(7),NPT3)

C1 = GAMMA
T = TT
N2 = N

IF (SENSE LIGHT 1) 60,60
IB = 1
IW = 0

C 62 IB = IB+1
IW = IW+1
NM = IW

C IF (B(7,IB-1)) 100,90,90

CONTINUE
IF (XXA(7)) 870,81,81
N2 = N2+1
CALL SELECT (XXA,T,N2,-1)
GO TO 98
CALL SHOCK (-2,M1,T,XXA,XXB,B(1,IB-2),B(1,IB-1),W(1,IW),
1 XX3U,XX3,DUM,C1,DUM,FSM)
M1 = M1

C GO TO (85,110,110,110,86,87,110),M1
85 XX3U(7) = 0.0
XX3(7) = B(7,IB-1)
CALL DMOVE (W(1,IW+1),XX3U)
CALL DMOVE (W(1,IW+2),XX3)
CALL DMOVE (B(1,1),XX3U)
CALL DMOVE (B(1,2),XX3)

```

```

IB = 2
NN = IW
IW = IW+2
NPT3 = 12345
CALL DMOVE (B(1,3),XX3)
SENSE LIGHT 1
GO TO 91

C
C CHARACTERISTIC IS COMPLETE.
C
86 IWW = IW
MM1 = 1
N = N2-1
GO TO 200

C
87 IF (XXA(7)) 870,875,875
870 MM1 = 3
IWW = IW
N = N2
GO TO 200

875 CALL DMOVE (XXB,XXA)
CALL SELECT (XXA,T,N2,1)
GO TO 83

C
90 CALL DMOVE (XX3,B(1,IB))
IF (NPT3) 999,901,900
901 IF (B(7,IB+1)) 999,91,97
900 IF (NPT3-12345) 97,910,999
910 IF (SENSE LIGHT 1) 80,911
911 IB = IB-1
GO TO 80

91 IF (T) 95,95,92
92 CALL FDPT (W(1,NN),B(1,IB),W(1,IW+1),C1,M1)
GO TO 62
95 CALL FDPT (B(1,IB),W(1,NN),W(1,IW+1),C1,M1)
GO TO 62
97 IB = IB+2
GO TO 91

C
98 IF (T) 980,980,981
980 CALL FDPT (XXA,B(1,IB-2),XXB,C1,M1)

```

```

950JF038
950JF039
950JF040
950JF041
950JF042
950JF043
950JF044
950JF045
950JF046
950JF047
950JF048
950JF049
950JF050
950JF051
950JF052
950JF053
950JF054
950JF055
950JF056
950JF057
950JF058
950JF059
950JF060
950JF061
950JF062
950JF063
950JF064
950JF065
950JF066
950JF067
950JF068
950JF069
950JF070
950JF071
950JF072
950JF073
950JF074
950JF075
950JF076
950JF077
950JF078

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981	90 TO 83	950JF079
	CALL FDPT (B(1,IB-2),XXA,XXB,C1,M1)	950JF080
110	GO TO 83	950JF081
	MM1 = 2	950JF082
	GO TO 200	950JF083
C		950JF084
100	IF (B(7,IB)) 102,101,102	950JF085
101	IF (B(7,IB+1)) 999,104,103	950JF086
103	CALL BODYPT (T,B(1,IB-1),B(1,IB+2),W(1,IW),C1,M1)	950JF087
	IB = IB+2	950JF088
	GO TO 105	950JF089
104	CALL BODYPT (T,B(1,IB-1),B(1,IB),W(1,IW),C1,M1)	950JF090
105	IW = 0	950JF091
	W(7,1) = B(7,1)	950JF092
	M1 = M1	950JF093
	GO TO (62,999),M1	950JF094
102	IB = 6	950JF095
	CALL DMOVE (W(1,1),B(1,IB))	950JF096
	N2 = N2+1	950JF097
	CALL SELECT (XXA,T,N2,0)	950JF098
	GO TO 98	950JF099
999	CALL DUMP	950JF100
200	RETURN	950JF101
	END	

```

* SUBROUTINE MCAL (XM1,G,DEL,XM2,
  LABEL
950JAA
C XM1 = INITIAL MACH NO. (INPUT)
C G = GAMMA
C DEL = TURN ANGLE IN RADIAN (INPUT)
C .....DEL = (+) EXPANSION FLOW
C .....DEL = (-) COMPRESSION FLOW
C XM2 = FINAL MACH NO. (OUTPUT)
C DIMENSION X(100),Y(100),A(200)
10 ZNUF(SM) = ATANF(C1*SM)/C1-ATANF(SM)
  FORMAT (7H NU = E12.5,10H NU/G = E12.5)
  IF (GI-G) 1,3,1
1 YMAX = 2.3
  DX = YMAX*1.3/99.
  GI = G
  C1 = SQRTF((GI-1.)/(GI+1.))
  DO 2 I=1,100
  XI = 1-1
  X(I) = EXPF (XI*DX)
  SSM = SQRTF(X(I)**2-1.)
  Y(I) = ZNUF(SSM)
2 CONTINUE
  XM = X(30)
  DY2 = XM*(1.+(GI-1.)*XM*XM/2.)/SSM
  CALL CURFIT (Y,X,A,100,0.,DY2,2,1)
3 SSM = SQRTF (XM1*XM1-1.)
  XU2 = ZNUF(SSM)+DEL
  CALL CURVE (A,Y,X,XU2,XM2,ANY,100,3)
101 RETURN
  END
950JAA00
950JAA
950JAA01
950JAA02
950JAA03
950JAA04
950JAA05
950JAA06
950JAA07
950JAA08
950JAA09
950JAA10
950JAA11
950JAA12
950JAA13
950JAA14
950JAA15
950JAA16
950JAA17
950JAA18
950JAA19
950JAA20
950JAA21
950JAA22
950JAA23
950JAA24
950JAA25
950JAA26
950JAA27

```



RETURN  
END

950JBB38

```

SUBROUTINE EXPAN (M1,STH,GAMMA,W,IW)
  * LABEL
  950JCC
C
C   DIMENSION W(10,100)
C
C   C1 = GAMMA
C3 = C1/(C1-1.0)
C10 = (C1-1.0)/2.0
DEL = STH-W(4,IW)
XM1 = 1.0/SINF(W(5,IW))
C
C   CALL MCAL (XM1,C1,DEL,XM2)
C
C   XM2SQ = XM2**2
IW = IW+1
W(1,IW) = W(1,IW-1)
W(2,IW) = W(2,IW-1)
W(3,IW) = (1.0+C10*XM2SQ)**(-C3)*W(6,IW-1)
W(4,IW) = STH
W(5,IW) = ATANF(1.0/SQRTF(XM2SQ-1.0))
W(6,IW) = W(6,IW-1)
C
C   RETURN
C   END
950JCC00
950JCC
950JCC01
950JCC02
950JCC03
950JCC04
950JCC05
950JCC06
950JCC07
950JCC08
950JCC09
950JCC10
950JCC11
950JCC12
950JCC13
950JCC14
950JCC15
950JCC16
950JCC17
950JCC18
950JCC19
950JCC20
950JCC21

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<pre> *          SUBROUTINE CONT5 (W,TT,GAMMA,FSM,NN,M1)           LABEL           950JG C          ROUTINE TO CONTROL THE CALCULATION OF C          SHOCK-BODY INTERACTION AND THE FIRST C          CHARACTERISTIC DOWNSTREAM. C          T NEGATIVE UPPER BODY. C          T POSITIVE LOWER BODY. C          K IS TAPE NUMBER. C C          DIMENSION B(10,100),W(10,100),XXA(10),XXB(10),XX2(10) C          EQUIVALENCE (NPTA,XXA(10)),(NPTB,XXB(10)) C C          C1 = GAMMA C          T = TT C          IF (T) 199,199,198 198      K = 4 C          GO TO 197 199      K = 3 197      BACKSPACE K           READ TAPE K,B C           DO 10 I=2,20           IF (B(7,I)) 10,10,15 10      CONTINUE           WRITE OUTPUT TAPE 6,500           FORMAT (//30H DATA FOR SHOCK4 IS INCORRECT.)           CALL DUMP C           15      IB = I           N = IB+1           18      CALL SHOCK4 (-T,B(1,IB),B(1,N),B(1,1),B(1,IB-1),W(1,1),           1          W(1,2),C1,M1)           M1 = M1           GO TO (30,999,20),M1           20      N = N+1           GO TO 18 C           30      STH = W(4,1) </pre>	<pre> 950JG000 950JG 950JG001 950JG002 950JG003 950JG004 950JG005 950JG006 950JG007 950JG008 950JG009 950JG010 950JG011 950JG012 950JG013 950JG014 950JG015 950JG016 950JG017 950JG018 950JG019 950JG020 950JG021 950JG022 950JG023 950JG024 950JG025 950JG026 950JG027 950JG028 950JG029 950JG030 950JG031 950JG032 950JG033 950JG034 950JG035 950JG036 950JG037 </pre>
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W(7,1) = B(7,1)
CALL SHK1 (T,SH,W(1,2),W(1,3),C1,M1)
CALL DMOVE (XXA,B(1,N))
CALL FDPT (W(1,2),XXA,XXB,C1,M1)
40 CALL SHOCK (-1,M1,T,XXA,XXB,W(1,2),W(1,3),XX2,W(1,4),
1 W(1,5),W(1,6),C1,DUM,FSM)
M1 = M1
GO TO (50,999,999,999,999,70,999),M1
70 CALL DMOVE (XXB,XXA)
BACKSPACE K
BACKSPACE K
READ TAPE K,B
DO 80 I=1,100
CALL DMOVE (XXA,B(1,I))
IF (NPTA-NPTB) 80,40,80
80 CONTINUE
C
50 W(7,5) = W(7,3)
W(7,6) = W(7,1)
NN = NPTA
RETURN
999 WRITE OUTPUT TAPE 6,501
501 FORMAT (//24H ERROR IN CONTS ROUTINE.)
CALL DUMP
END

```

```

950JG038
950JG039
950JG040
950JG041
950JG042
950JG043
950JG044
950JG045
950JG046
950JG047
950JG048
950JG049
950JG050
950JG051
950JG052
950JG053
950JG054
950JG055
950JG056
950JG057
950JG058
950JG059
950JG060
950JG061

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```

SUBROUTINE CONT6 (DATA,GAMMA)
  LABEL
* 950JH
  DIMENSION W(10,100),B(10,100),XX1(100),XX2(100),
1 YY1(100),YY2(100)
  DIMENSION DATA(10,8),XX1(10),XX2(10)
  DIMENSION TH(20),PPU(20),PPD(20)
  EQUIVALENCE (XX1(7),NPT1)
500 FORMAT (1P2E15.5)
501 FORMAT (10X1P2E15.5)
502 FORMAT (1P6E15.5)
  DINTPF(XY1,XY2,XY3,XY4,XY) = XY2+(XY4-XY2)/(XY3-XY1)*(XY-XY1)
  REWIND 2
  READ TAPE 2
  READ TAPE 2
  REWIND 4
  NP1 = 0
  DO 40 I=1,200
    READ TAPE 4,W
    IF (W(1,100)-32000.0) 10,50,10
    CALL MOVE1 (IBB,W)
    CALL DMOVE (XX1,W(1,IBB-1))
    IF (NPT1+2) 20,40,40
20  NP1 = NP1+1
    XXX1(NP1) = XX1(1)
    YY1(NP1) = XX1(2)
    WRITE TAPE 2,XX1
40  CONTINUE
50  BACKSPACE 4
    B(1,100) = 3000.0
    WRITE TAPE 9,B
    END FILE 9
    REWIND 9
    NP2 = 0
    DO 70 I=1,200
      READ TAPE 9,W
      WRITE TAPE 4,W
      IF (W(1,100)-3000.0) 60,80,60
60  DO 65 II=1,100
      CALL DMOVE (XX1,W(1,II))

```

```

950JH000
950JH
950JH001
950JH002
950JH003
950JH004
950JH005
950JH006
950JH007
950JH008
950JH009
950JH010
950JH011
950JH012
950JH013
950JH014
950JH015
950JH016
950JH017
950JH018
950JH019
950JH020
950JH021
950JH022
950JH023
950JH024
950JH025
950JH026
950JH027
950JH028
950JH029
950JH030
950JH031
950JH032
950JH033
950JH034
950JH035
950JH036
950JH037

```

```

61 IF (NP1-12345) 61,70,61
62 IF (NP1) 63,65,62
64 IF (XXX2(NP2)-XX1(1)) 64,65,64
    NP2 = NP2+1
    XXX2(NP2) = XX1(1)
    YY2(NP2) = XX1(2)
65 CONTINUE
70 CONTINUE
80 CONTINUE
    CALL MEET (XXX1,YY1,NP1,XXX2,YY2,NP2,X,Y,DY1,DY2)
C
    REWIND 2
    READ TAPE 2
    READ TAPE 2
    READ TAPE 2,XX1
110 IF (XX1(1)-X) 110,120,120
120 BACKSPACE 2
    BACKSPACE 2
    READ TAPE 2,XX2
    DATA(1,1) = X
    DATA(2,1) = Y
    DATA(3,1) = DINTPF(XX1(1),XX1(3),XX2(1),XX2(3),X)
    DATA(4,1) = ATANF(DY1)
    DATA(5,1) = DINTPF(XX1(1),XX1(5),XX2(1),XX2(5),X)
    DATA(6,1) = DINTPF(XX1(1),XX1(6),XX2(1),XX2(6),X)
    DATA(7,1) = XX2(7)
    W1 = ATANF(DY2)-DATA(4,1)
    CALL OBLSHK (DATA(1,1),W1,DATA(1,2),GAMMA)
    B(1,100) = 32000.0
    WRITE TAPE 3,B
130 BACKSPACE 3
    BACKSPACE 3
    READ TAPE 3,W
    CALL MOVE1 (IBB,W)
    IF (X-W(1,IBB-1)) 130,130,140
140 CALL DMOVE (XX1,W(1,IBB-1))
    READ TAPE 3,W
    CALL MOVE1 (IBB,W)
    CALL DMOVE (XX2,W(1,IBB-1))
    DATA(1,3) = X
    DATA(2,3) = Y
950JH038
950JH039
950JH040
950JH041
950JH042
950JH043
950JH044
950JH045
950JH046
950JH047
950JH048
950JH049
950JH050
950JH051
950JH052
950JH053
950JH054
950JH055
950JH056
950JH057
950JH058
950JH059
950JH060
950JH061
950JH062
950JH063
950JH064
950JH065
950JH066
950JH067
950JH068
950JH069
950JH070
950JH071
950JH072
950JH073
950JH074
950JH075
950JH076
950JH077
950JH078

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```

DATA(3,3) = DINTPF(XX1(1),XX1(3),XX2(1),XX2(3),X)
DATA(4,3) = DATA(4,1)
DATA(5,3) = DINTPF(XX1(1),XX1(5),XX2(1),XX2(5),X)
DATA(6,3) = DINTPF(XX1(1),XX1(5),XX2(1),XX2(6),X)
DATA(7,3) = XX2(7)
SPTH = DATA(4,2)-DATA(4,1)
DTH = SPTH/12.0
TH(1) = DATA(4,2)-3.5*DTH
DO 290 J=1,5
  L = 9
200 DO 250 I=1,L
    STH = TH(I)
    IF (STH-DATA(4,3)) 999,999,210
210 CALL SHK1 (1,0,STH,DATA(1,3),DATA(1,4),GAMMA,M1)
    IF (DATA(4,2)-STH) 220,220,230
220 CALL DMOVE (W,DATA(1,2))
    IW=1
    CALL EXPAN (M1,STH,GAMMA,W,IW)
    PPD(I) = W(3,IW)
    CALL DMOVE (DATA(1,5),W(1,IW))
    GO TO 240
230 CALL SHK1 (-1,0,STH,DATA(1,2),DATA(1,5),GAMMA,M1)
    PPD(I) = DATA(3,5)
240 PPU(I) = DATA(3,4)
    TH(I+1) = TH(I)+DTH
250 CONTINUE
C
    IF (L-9) 270,260,270
260 L = 1
    CALL MEET (TH,PPU,9,TH,PPD,9,TH(1),P,DY1,DY2)
    GO TO 200
C
270 DTH = DTH/2.0
    TH(1) = TH(1)-4.*DTH
    IF (ABSF(DATA(3,5)-DATA(3,4))-0.0001*DATA(3,4)) 300,300,290
290 CONTINUE
C
300 NPT1 = 12345
    RETURN
999 CALL DUMP
    END

```

950JH079  
 950JH080  
 950JH081  
 950JH082  
 950JH083  
 950JH084  
 950JH085  
 950JH086  
 950JH087  
 950JH088  
 950JH089  
 950JH090  
 950JH091  
 950JH092  
 950JH093  
 950JH094  
 950JH095  
 950JH096  
 950JH097  
 950JH098  
 950JH099  
 950JH100  
 950JH101  
 950JH102  
 950JH103  
 950JH104  
 950JH105  
 950JH106  
 950JH107  
 950JH108  
 950JH109  
 950JH110  
 950JH111  
 950JH112  
 950JH113  
 950JH114  
 950JH115  
 950JH116  
 950JH117  
 950JH118



```

          TH(I) = XX3(4)
          XX3(4) = XX3(4) + DTH
C
          IF (XX3(1)-XX5(1)) 40,40,50
40      PPI(I) = XX3(3)
          PP5(I) = PPUDF(XX3(1),XX5(1),XX7(1),XX5(3),XX7(3))
          GO TO 10
50      PP5(I) = XX5(3)
          PPI(I) = PPUDF(XX5(1),XX3(1),XX1(1),XX3(3),XX1(3))
10      CONTINUE
C
          IF (L-9) 70,60,70
60      CALL MEET (TH,PPI,L,TH,PP5,L,XX3(4),XX3(3),DY1,DY2)
          XX5(4) = XX3(4)
          XX5(3) = XX3(3)
          L = 1
          DTH = 0.0
          GO TO 7
C
70      L = 9
          DOTH = DOTH/2.
          IF (ABSF(PPI(1)-PP5(1))-0.0001*XX1(3)) 30,30,20
20      CONTINUE
C
30      CALL DMOVE (ZZ3,XX3)
          CALL DMOVE (ZZ5,XX5)
          RETURN
          END
950JE038
950JE039
950JE040
950JE041
950JE042
950JE043
950JE044
950JE045
950JE046
950JE047
950JE048
950JE049
950JE050
950JE051
950JE052
950JE053
950JE054
950JE055
950JE056
950JE057
950JE058
950JE059
950JE060
950JE061
950JE062
950JE063
950JE064

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*          950JD
SUBROUTINE CHLIN4 (B,W,GAMMA,TT,IBB,IWW,M1,FSMM)
  LABEL
  950JD
C          T = +1 RIGHT RUNNING CHARACTERISTIC
C          T = -1 LEFT RUNNING CHARACTERISTIC
C
  DIMENSION B(10,100),W(10,100),XX1(10),XXA(10),XXB(10),XX2(10),
1 XX3(10),XX3U(10),XX5(10)
EQUIVALENCE (NPT1,XX1(7)),(NPT2,XX2(7))
C1 = GAMMA
T = TT
FSM = FSMM
IF (T) 10,10,20
10 NPT = 11
GO TO 30
20 NPT = 21
30 CONTINUE
60 IB = 2
IW = 1
CALL BODYPT (-T,B(1,IB-1),B(1,IB),W(1,IW),C1,M1)
M1 = M1
GO TO (61,999),M1
C
61 W(7,1) = B(7,1)
62 IW = IW+1
63 IB = IB+1
C
65 CALL DMOVE (XX1,B(1,IB))
IF (NPT1-NPT) 69,66,69
66 IW = IW-1
660 CALL DMOVE (XXA,W(1,IW-1))
CALL DMOVE (XXB,W(1,IW))
IF (XXB(7)) 685,662,662
662 N = IB+1
661 CALL DMOVE (XX2,B(1,N))
67 CALL SHOCK (-2,M1,T,XXA,XXB,B(1,IB-1),B(1,IB),XX2,XX3U,XX3,
1 XX5,C1,SW,FSM)
M1 = M1
GO TO (68,999,999,999,681,682,683),M1
950JD000
950JD
950JD001
950JD002
950JD003
950JD004
950JD005
950JD006
950JD007
950JD008
950JD009
950JD010
950JD011
950JD012
950JD013
950JD014
950JD015
950JD016
950JD017
950JD018
950JD019
950JD020
950JD021
950JD022
950JD023
950JD024
950JD025
950JD026
950JD027
950JD028
950JD029
950JD030
950JD031
950JD032
950JD033
950JD034
950JD035
950JD036
950JD037

```

68	XX3U(7) = 0.0	950JD038
	XX3(7) = B(7,IB)	950JD039
	CALL DMOVE (W(1,IW),XX3U)	950JD040
	CALL DMOVE (W(1,IW+1),XX3)	950JD041
	IW = IW+1	950JD042
	IB = N-1	950JD043
	GO TO 62	950JD044
C		950JD045
681	IF (NPT2) 210,200,210	950JD046
200	N = N+1	950JD047
	GO TO 661	950JD048
210	CALL MOVE1 (IB,B)	950JD049
215	CALL DMOVE (XX1,B(1,IB))	950JD050
	IF (NPT1) 217,220,220	950JD051
217	IF (NPT1+2) 220,230,230	950JD052
220	CALL DMOVE (B(1,IB+1),B(1,IB))	950JD053
	IB = IB-1	950JD054
	GO TO 215	950JD055
230	DO 240 I=1,6	950JD056
	B(I,2) = (B(I,3)+B(I,1))/2.0	950JD057
240	CONTINUE	950JD058
	GO TO 60	950JD059
682	IF (XXA(7)) 685,684,686	950JD060
684	IW = IW-1	950JD061
	GO TO 660	950JD062
683	IW = IW+1	950JD063
	GO TO 660	950JD064
685	M1 = 2	950JD065
	GO TO 75	950JD066
686	M1 = 3	950JD067
	GO TO 75	950JD068
C		950JD069
69	IF (B(7,IB)) 692,694,690	950JD070
690	IB = IB+1	950JD071
	GO TO 65	950JD072
692	CALL DMOVE (XX1,B(1,IB+1))	950JD073
	IF (NPT1-12345) 63,694,63	950JD074
694	IF (T) 390,390,392	950JD075
390	CALL FDPT (W(1,IW-1),B(1,IB),W(1,IW),C1,M1)	950JD076
	GO TO 394	950JD077
392	CALL FDPT (B(1,IB),W(1,IW-1),W(1,IW),C1,M1)	950JD078

950JD079  
950JD080  
950JD081  
950JD082  
950JD083  
950JD084  
950JD085  
950JD086  
950JD087  
950JD088

```
394 CONTINUE = B(10,IB)
    W(10,IW) = B(10,IB)
    CALL DMOVE (XX1,B(1,IB))
    IF (NPT1) 70,62,62
70 M1 = 1
75 IB8 = IB
    IW = IW
    M11 = M1
    RETURN
999 CALL DUMP
    END
```

```

C
SURROUTINE SHOCK4 (AA,XX1,XX2,XX5,XX7,XX3U,XX3,GAMMA,M1)
C
DIMENSION XX1(10),XX2(10),XX3U(10),XX3(10)
DIMENSION XX5(10),XX7(10)
C
21  FORMAT (1P6F15.5,I15)
C
TANF(XXX) = SIN(XXX)/COS(XXX)
C
X1 = XX1(1)
Y1 = XX1(2)
P1 = XX1(3)
TH1 = XX1(4)
ZMU1 = XX1(5)
R1 = XX1(6)
W1 = ABSF(XX1(8))
C
X2 = XX2(1)
Y2 = XX2(2)
P2 = XX2(3)
TH2 = XX2(4)
ZMU2 = XX2(5)
R2 = XX2(6)
W2 = XX2(8)
C
X7 = XX7(1)
Y7 = XX7(2)
P7 = XX7(3)
TH7 = XX7(4)
ZMU7 = XX7(5)
R7 = XX7(6)
W7 = XX7(8)
C
X5 = XX5(1)
Y5 = XX5(2)
P5 = XX5(3)
TH5 = XX5(4)
ZMU5 = XX5(5)
R5 = XX5(6)
W5 = XX5(8)
A = AA
C
950J1000
950J1001
950J1002
950J1003
950J1004
950J1005
950J1006
950J1007
950J1008
950J1009
950J1010
950J1011
950J1012
950J1013
950J1014
950J1015
950J1016
950J1017
950J1018
950J1019
950J1020
950J1021
950J1022
950J1023
950J1024
950J1025
950J1026
950J1027
950J1028
950J1029
950J1030
950J1031
950J1032
950J1033
950J1034
950J1035
950J1036
950J1037
950J1038
950J1039

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```

C
C
C1 = GAMMA
RR = .5
C2 = 1./(1.-C1)
C3 = C1/(C1-1.)
C4 = 2.*C1/(C1+1.)
C5 = (C1-1.)/(C1+1.)
C7 = (C1-1.)/C1
C11 = (C1-1.)/(2.*C1)
C12 = 2./(1.-C1)
T1 = TANF(TH7 + A*W1)
T2 = TANF(TH5)
X3 = (Y1 - X1*T1 + X5*T2 - Y5)/(T2-T1)
W3 = W1
CALL LOCATE (1,-A,ITT,AC,BC,CC,DC,X3)
R3U = R5
P3U = P7
ZMU3U = ZMU7
P3LS = 1000.
TH3U = ATANF((3.*AC*X3 + 2.*BC)*X3 + CC)
DO 425 J = 1,100

C
C
DO 310 I = 1,20
CALL LOCATE (0,-A,ITT,AC,BC,CC,DC,X3)
TH3U = ATANF((3.*AC*X3 + 2.*BC)*X3 + CC)
T1 = (TH3U + TH7 + A* (W3+W1))/2.
T1 = TANF(T1)
FX = (X3*(AC *X3 + BC ) + CC )*X3 + DC - Y1 + T1*(X1-X3)
DFX = (3.*AC *X3 + 2.*BC )*X3 + CC - T1
IF (ABS(FDX)-.00000001) 20, 20,300

C
C
DDFX= FX/DFX
X3 = X3 - DDFX
IF (ABS(DDFX) - MAX1F(.00001*X3, .00001)) 20, 20,310

C
C
310 CONTINUE
C
20 Y3 = Y7 - T1 * (X7-X3)
T7 = TH3U + A*ZMU3U
T4 = TH7 + A*ZMU7
950J1040
950J1041
950J1042
950J1043
950J1044
950J1045
950J1046
950J1047
950J1048
950J1049
950J1050
950J1051
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950J1073
950J1074
950J1075
950J1076
950J1077
950J1078
950J1079
950J1080

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```

C
T6 = TH5 + A*ZMU5
T8 = Y7 - Y5
T9 = X7 - X5
T10 = Y5 - Y3
T11 = X5 - X3
DO 55 KK = 1,100
T3 = (RR * (T4-T6) + (T6+T7))/2.
T12 = TANF(T3)
FR = RR * T8/T9 + T10/T9 - (RR + T11/T9)* T12
FPR = T8/T9 - T12 - (RR+T11/T9) * .5 * (T4-T6)/COSF(T3)**2
IF (ABSF(FPR) - .00000001) 57,57,52
52 DRR = FR/FPR
RR = RR - DRR
C
50 CONTINUE
C
51 IF (ABSF(DRR) - .00000001) 57,57,55
55 CONTINUE
C
57 Y4 = Y5 + RR* T8
X4 = X5 + RR* T9
TH4 = TH5 + RR* (TH7-TH5)
P4 = P5 + RR* (P7-P5)
R4 = R5 + RR* (R7-R5)
ZMU4 = ZMU5 + RR* (ZMU7-ZMU5)
PB4 = (P4+P3U)/2.
ZMUB4 = (ZMU4+ZMU3U)/2.
THB4 = (TH4+TH3U)/2.
YB4 = (Y4 + Y3)/2.
T2 = (T7 + TH4 + A*ZMU4)/2.
C
P3U = P4+C1*PB4*(-A*(TH3U-TH4)/(COSF(ZMUB4)*SINF(ZMUB4)))
T30 = P3U/R3U
C
IF (T30) 370,70,70
C
T30 = C12 * (1.- T30**(-C7)) - 1.
IF (T30) 370,370,80
80 ZMU3U= ATANF(SQRTF(1./T30))
C

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950J1081
950J1082
950J1083
950J1084
950J1085
950J1086
950J1087
950J1088
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950J1090
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950J1092
950J1093
950J1094
950J1095
950J1096
950J1097
950J1098
950J1099
950J1100
950J1101
950J1102
950J1103
950J1104
950J1105
950J1106
950J1107
950J1108
950J1109
950J1110
950J1111
950J1112
950J1113
950J1114
950J1115
950J1116
950J1117
950J1118
950J1119
950J1120
950J1121

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C 100 ZMU3U = 1./SINF(ZMU3U )
      T32 = ZMU3U **2
      T29 = SINF(2.*W3)
      T31 = SINF(W3)**2
      DEL3 = ATANF((T32*T29 - 2./TANF(W3))/(T32* (C1 + COSF(2.*W3))+2.))
      TH3 = TH3U + A*DEL3
      ERASB = C4*(T32*T31 - C11)
      P3 = P3U *ERASB
      R3 = ((T32*T31)/(C5*((T32*T31)-C12)))*C3*ERASB**C2 * R3U
      T30 = P3 /R3
      IF (T30) 370,370,380
C 370 M1 = 2
      GO TO 430
C 380 T30 = C12 * (1. - T30**(-C7)) -1.
      IF (T30 - .04) 370,370,390
C 390 ZMU3 = ATANF(SQRTF(1./T30))
      IF (ABSF(P3 - P3LS) - .001*P3) 428,428,400
C 400 P3LS = P3
C
      T4 = TH1 + A*ZMU1
      T6 = TH2 + A*ZMU2
      T7 = TH3 + A*ZMU3
      T8 = Y2 - Y1
      T9 = X2 - X1
      T10 = Y1 -Y3
      T11 = X1 - X3
      DO 30 KK = 1,100
      T3 = (RR*(T6-T4) + (T4+T7))/2.
      T12 = TANF(T3)
      FR = RR * T8/T9 + T10/T9 - (RR + T11/T9)* T12
      FPR = T8/T9 - T12 - (RR+T11/T9) * .5 * (T6-T4)/COSF(T3)**2
      IF (ABSF(FPR) -.00000001) 31,31,42
      DRR = FR/FPR
      RR = RR - DRR
      42
      40 WRITE OUTPUT TAPE 6,21,RR,DRR,FR,FPR
950J1122
950J1123
950J1124
950J1125
950J1126
950J1127
950J1128
950J1129
950J1130
950J1131
950J1132
950J1133
950J1134
950J1135
950J1136
950J1137
950J1138
950J1139
950J1140
950J1141
950J1142
950J1143
950J1144
950J1145
950J1146
950J1147
950J1148
950J1149
950J1150
950J1151
950J1152
950J1153
950J1154
950J1155
950J1156
950J1157
950J1158
950J1159
950J1160
950J1161
950J1162

```

```

45 IF (ABS(F(DRR) - .0000001) 31,31,30
30 CONTINUE
31 IF (RR) 220,210,210
210 IF (RR - 1.) 270,270,220
220 IF (NPT2) 370,230,230
230 M1 = 3
C
C USE THE NEXT POINT ON THE CHARACTERISTIC AS
C A POINT 2.
C
C GO TO 430
C
270 Y4 = Y1 + RR*T8
X4 = X1 + RR*T9
TH4 = TH1 + RR*(TH2-TH1)
P4 = P1 + RR*(P2-P1)
R4 = R1 + RR*(R2-R1)
ZMU4 = ZMU1 + RR*(ZMU2-ZMU1)
T28 = SIN(DEL3)**2
DPDW = P3U *C4*T32*T29
DTHDW = (C1+1.)*T28*T31*T32**2/(T32*T31-1.)*2-SIN(2.*DEL3)/T29
T13 = (TH4 + TH3)/2.
T60 = (TH4 + A*ZMU4)/2.
T11=(P4 + P3U)/2.
T12= (ZMU4 + ZMU3)/2.
T34 = (Y4 + Y3)/2.
DW3 = -(P3-P4)/(C1*T11)+A*(TH3-TH4)/((COSF(T12))*(SINF(T12))))
W3 = W3 +DW3/(DPDW/(C1*T11) + DTHDW/TANF(T12))
C
C CONTINUE
425 M1 = 1
428 XX3U(1) = X3
XX3U(2) = Y3
XX3U(3) = P3U
XX3U(4) = TH3U
XX3U(5) = ZMU3U
XX3U(6) = R3U
XX3U(7) = 0.0
XX3(1) = X3
XX3(2) = Y3
950J1163
950J1164
950J1165
950J1166
950J1167
950J1168
950J1169
950J1170
950J1171
950J1172
950J1173
950J1174
950J1175
950J1176
950J1177
950J1178
950J1179
950J1180
950J1181
950J1182
950J1183
950J1184
950J1185
950J1186
950J1187
950J1188
950J1189
950J1190
950J1191
950J1192
950J1193
950J1194
950J1195
950J1196
950J1197
950J1198
950J1199
950J1200
950J1201
950J1202
950J1203

```

950J1204  
 950J1205  
 950J1206  
 950J1207  
 950J1208  
 950J1209  
 950J1210

XX3(3) = P3  
 XX3(4) = TH3  
 XX3(5) = ZMU3  
 XX3(6) = R3  
 XX3(7) = XX1(7)  
 XX3(8) = SIGNF(W3,XX1(8))  
 430 RETURN  
 END

```

C      PROGRAM TO SET UP DATA FOR BOUNDARY LAYER.
*      LABEL
950J5000
C
950J5001
950J5002
950J5003
950J5004
950J5005
950J5006
950J5007
950J5008
950J5009
950J5010
950J5011
950J5012
950J5013
950J5014
950J5015
950J5016
950J5017
950J5018
950J5019
950J5020
950J5021
950J5022
950J5023
950J5024
950J5025
950J5026
950J5027
950J5028
950J5029
950J5030
950J5031
950J5032
950J5033
950J5034
950J5035
950J5036
950J5037
C
C      DIMENSION ARRAY(12),UL(200),SL(200),M(10),B(10,100),BU(2,100) ,
1      RL(2,100),UU(200),SU(200),XU(200),YU(200),XL(200),YL(200)
C      DIMENSION YINTGU(200),YINTGL(200),W(10,100)
C      DIMENSION AC1(6,20),AC2(6,20)
C
410  FORMAT (20X43HBOUNDARY LAYER INPUT DATA - UPPER SURFACE///
110X6HT2T1 =1PE15.5/10X6HP2P1 =1PE15.5/10X6HU2U1 =1PE15.5/
210X6HP3P2 =1PE15.5//
39X1HX,19X1HY,12X16HSURFACE DISTANCE,9X8HVELOCITY//
4(1PE15.5,1P3E20.5))
C
420  FORMAT (20X43HBOUNDARY LAYER INPUT DATA - LOWER SURFACE///
110X6HT2T1 =1PE15.5/10X6HP2P1 =1PE15.5/10X6HU2U1 =1PE15.5/
210X6HP3P2 =1PE15.5//9X1HX,19X1HY,12X16HSURFACE DISTANCE,
39X8HVELOCITY//(1PE15.5,1P3E20.5))
C
P3P2U = 1.0
P3P2L = 1.0
REWIND 2
READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY
IF (M(1)-1) 200,210,200
200  READ TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R2,
1      B,W,N,((BU(I,L),I=1,2),L=1,N),((BL(I,L),I=1,2),L=1,N)
210  READ TAPE 2,AC1,AC2,N1,N2
REWIND 2
IF (M(10)-1)3,2,1
1      CALL EXIT
C
2      M(10) = 2
IF (M(1)-1) 225,220,225
220  WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY
GO TO 228
225  WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R2,
1      B,W,N,((BU(I,L),I=1,2),L=1,N),((BL(I,L),I=1,2),L=1,N)
228  WRITE TAPE 2,AC1,AC2,N1,N2
CALL CHAIN (10,8)
C

```

```

3      M(10) = 1
      IF (M(1)-1) 235,230,235
230    WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY
      GO TO 238
235    WRITE TAPE 2,GAMMA,FSM,FSP,FST,M,ARRAY,RBAR,R1,R2,
1      B*W,N,((BU(I,L),I=1,2),L=1,N),((BL(I,L),I=1,2),L=1,N)
238    WRITE TAPE 2,AC1,AC2,N1,N2
      CALL LOCATE (-1,I,ITT,DUM,DUM,DUM,DUM)
      REWIND 3
      REWIND 4
      REWIND 9
      IF (M(1)-2) 5,8,5
5      N = 0
      P1 = (1.0+(GAMMA-1.0)/2.0*FSM**2)**(-GAMMA/(GAMMA-1.0))
      GO TO 12
8      DO 10 I=1,N
      UU(I) = BU(2,I)
      SU(I) = BU(1,I)*R1
      UL(I) = BL(2,I)
      SL(I) = BL(1,I)*R2
      READ TAPE 3
      READ TAPE 4
      CONTINUE
10     J = 0
12     K = N
      B(1,100) = 100.0
15     IF (B(1,100)-3333.0) 20,40,20
20     READ TAPE 3,B
      WRITE OUTPUT TAPE 6,700,B(1,1),B(2,1),B(3,1),B(1,100)
700    FORMAT (1P4E16.5)
      IF (B(7,1)) 22,15,15
22     IF (J) 25,38,25
25     IF (B(1,1)-XU(J)) 30,15,30
38     B(1,2) = 100.0
30     J = J+1
      K = K+1
      CALL USPREP (-1.0,B,XU(J),YU(J),YINTGU(J),UU(K),FST)
      IF (B(1,1)-B(1,2)) 15,32,15
32     J = J+1
      K = K+1
      CALL USPREP (-1.0,B(1,3),XU(J),YU(J),YINTGU(J),UU(K),FST)

```

```

          P3P2U = B(3,3)/B(3,2)
          GO TO 15
C
40      I = 0
        L = N
        R(1,100) = 100.0
50      READ TAPE 4,R
        WRITE OUTPUT TAPE 6,700,B(1,1),B(2,1),B(3,1),B(1,100)
        IF (B(1,100)-3333.0) 60,90,60
60      IF (B(7,1)) 65,50,50
65      IF (I) 66,67,66
66      IF (B(1,1)-XL(I)) 70,50,70
67      B(1,2) = 100.0
70      I = I+1
        L = L+1
        CALL USPREP (1.0,B,XL(I),YL(I),YINTGL(I),UL(L),FST)
        IF (B(1,1)-B(1,2)) 50,80,50
80      I = I+1
        L = L+1
        CALL USPREP (1.0,B(1,3),XL(I),YL(I),YINTGL(I),UL(L),FST)
        P3P2L = B(3,3)/B(3,2)
        GO TO 50
C
90      IF (K-200) 100,100,888
100     IF (L-200) 110,110,888
110     IF (N) 116,115,116
115     N = 1
        SU(1) = 0.0
        SL(1) = 0.0
116     CALL SURFCL (XU,YU,YINTGU,J,N,SU(N))
        CALL SURFCL (XL,YL,YINTGL,I,N,SL(N))
        IF (M(1)-1) 120,130,120
120     TERM1 = FSM**2
        TERM2 = 2.0*GAMMA*TERM1
        TERM3 = GAMMA-1.0
        TERM4 = GAMMA+1.0
        P2P1U = (TERM2-TERM3)/TERM4
        T2T1U = ((TERM2-TERM3)*((TERM3*TERM1+2.0)/(TERM4**2*TERM1))
        U2U1U = (TERM3*TERM1+2.0)/(TERM4*TERM1)
        P2P1L = P2P1U
        T2T1L = T2T1U
950J5079
950J5080
950J5081
950J5082
950J5083
950J5084
950J5085
950J5086
950J5087
950J5088
950J5089
950J5090
950J5091
950J5092
950J5093
950J5094
950J5095
950J5096
950J5097
950J5098
950J5099
950J5100
950J5101
950J5102
950J5103
950J5104
950J5105
950J5106
950J5107
950J5108
950J5109
950J5110
950J5111
950J5112
950J5113
950J5114
950J5115
950J5116
950J5117
950J5118
950J5119

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```

130      U2U16 = U2U1U
      REWIND 3
      REWIND 4
      TERM5 = FSM*SQRTF(FST)
      READ TAPE 3,B
      P2P1U = B(3,1)/P1
      TERM1 = FSM**2*SINF(B(8,1))**2
      TERM2 = GAMMA-1.0
      T2T1U = (2.0*GAMMA*TERM1-TERM2)*(TERM2*TERM1+2.0)
      1 /((GAMMA+1.0)**2*TERM1)
      U2U1U = (SQRTF(FST*T2T1U)/SINF(B(5,1)))/TERM5
      READ TAPE 4,B
      P2P1L = B(3,1)/P1
      TERM1 = FSM**2*SINF(B(8,1))**2
      T2T1L = (2.0*GAMMA*TERM1-TERM2)*(TERM2*TERM1+2.0)
      1 /((GAMMA+1.0)**2*TERM1)
      U2U1L = (SQRTF(FST*T2T1L)/SINF(B(5,1)))/TERM5
140      CONTINUE
      UIU = UU(1)
      UIL = UL(1)
      WRITE TAPE 9,ARRAY,FSM,FST,FSP,UIU,T2T1U,P2P1U,U2U1U,K,R1,P3P2U
      WRITE TAPE 9,(SU(JJ),UU(JJ),JJ=1,K)
      WRITE TAPE 9,ARRAY,FSM,FST,FSP,UIL,T2T1L,P2P1L,U2U1L
      1 L,R2,P3P2L
      WRITE TAPE 9,(SL(JJ),UL(JJ),JJ=1,L)
      REWIND 9
      CALL PAGE2 (0,ARRAY)
      WRITE OUTPUT TAPE 6,410,T2T1U,P2P1U,U2U1U,P3P2U,
      1 (XU(JJ),YU(JJ),SU(JJ),UU(JJ),JJ=1,K)
      CALL PAGE2 (0,ARRAY)
      WRITE OUTPUT TAPE 6,420,T2T1L,P2P1L,U2U1L,P3P2L,
      1 (XL(JJ),YL(JJ),SL(JJ),UL(JJ),JJ=1,L)
      CALL CHAIN (10,8)
888      WRITE OUTPUT TAPE 6,400
999      CALL DUMP
400      FORMAT (32H THERE ARE TOO MANY BODY POINTS.)
      END

```

```

950J5129
950J5122
950J5123
950J5124
950J5125
950J5126
950J5127
950J5128
950J5129
950J5130
950J5131
950J5132
950J5133
950J5134
950J5135
950J5136
950J5137
950J5138
950J5139
950J5140
950J5141
950J5142
950J5143
950J5144
950J5145
950J5146
950J5147
950J5148
950J5149
950J5150
950J5151
950J5152
950J5153
950J5154
950J5155
950J5156

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```

* SUBROUTINE US PREP (T,XX1,X,Y,Y1,U,FST)
  LABEL
950JEE
    DIMENSION XX1(10)
    IF (T-2.0) 10,20,10
10  X = XX1(1)
    Y = XX1(2)
    CALL LOCATE (1,T,ITT,AC,BC,CC,DC,X)
    Y1 = SORTF(1.0+(X*(3.0*AC*X+2.0*BC)+CC)**2)
20  CONTINUE
    ZM2 = (1.0/SINF(XX1(5)))**2
    U = 49.1*SORTF(FST/(1.0+ZM2/5.0))
    RETURN
    END
950JEE00
950JEE
950JEE01
950JEE02
950JEE03
950JEE04
950JEE05
950JEE06
950JEE07
950JEE08
950JEE09
950JEE10

```

```
* SUBROUTINE SURFCL (X,Y,YINTG,J,N,S)
   LABEL
950JFF
C
C SUBROUTINE TO CALCULATE SURFACE DISTANCE.
C
C DIMENSION X(200),Y(200),S(200),YINTG(200),A(400)
C
C K = N
C CALL CURFIT (X,YINTG,A,J,0,0,2,2)
C
C DO 20 I=2,J
C CALL SIGMA (A,X,YINTG,J,X(I-1),X(I),SUM)
C S(K+1) = S(K)+SUM
C K = K+1
C CONTINUE
C 20
C RETURN
END
```

```

CMAIN.....2D=GENERAL
C 2-D (1) BOUNDARY-LAYER INPUT PROGRAM
C THIS PROGRAM REQUIRES.....

      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
      DIMENSION XI2U(201),DUK(201),AU(400)
      DIMENSION XI2R(201),DRK(201),AR(400)
      DIMENSION XX(201),YY(201),UU(201)
      DIMENSION XACT(2),ACT(2),YACT(2)

      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
      COMMON T,TG,TK,TE,P,PO,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,ISTAR
      COMMON RSTR,RSTRK,RSTRE
      COMMON XN,SIG1,RSIG,TGNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
      COMMON NU,XI2U,DUK,AU
      COMMON NR,XI2R,DRK,AR
      COMMON XNU1,XNU2,XNU3,NBC,XNOP
      COMMON T00,P00,QS2,KASE,RNOSE,QOPRM
      COMMON XACT,ACT,YACT,P3P2
      COMMON COM

C
99  FORMAT (8HORE/FT =E15.7)
100 FORMAT (33HERROR OCCURRED.....JOB TERMINATED )
108 FORMAT(10H0 I = ,I4.8H J = ,I2.08H V = ,E15.8, 8H 909JU145
1  T = ,E15.8,8H G = ,E15.8/09H A01 = E15.8,8H A02 = E15.8,8H A06 = 909JU150
2.8,8H A03 = E15.8,8H A04 = E15.8,8H A05 = E15.8/09H A06 = 909JU155
3 E15.8,8H A07 = E15.8,8H A08 = E15.8,8H A09 = E15.8,8H A10 909JU160
4 = E15.8/09H A11 = E15.8,8H A12 = E15.8,8H A13 = E15.8,8H 909JU165
5 A14 = E15.8,8H A15 = E15.8/09H A16 = E15.8,8H A17 = E15.8,8H 909JU170
68H A18 = E15.8,8H A19 = E15.8,8H A20 = E15.8/09H A21 = E15.8,8H 909JU175
75.8,8H A22 = E15.8,8H A23 = E15.8,8H A24 = E15.8,8H 909JU180
8 5HA25 =E15.8/4X7HXI-SQ =E13.6,6X4HCP =E13.6,6X4HU* =E13.6, 909JU185
9 6X4HT* =E13.6,3X7HF(0)* =E13.6) 909JU190
198 FORMAT (1HC5X6HDEL XIF8.5/6X7HDEL ETAF8.5/6X5HI-MAXI9/ 909JU195
1 6X7HI-FREQN17/6X5HI-MIDI9/6X5HJ-MAXI9/6X7HJ-FREQN18) 909JU200

```

```

200 1  FORMAT (1H038X5HSH9CK630X3H(1)8X1H*6X3H(2)64X1H*/2E15.7/
      2  E15.7,3H *E15.7/3X5HM(1)=F10.6,4X2HP E15.7,3H *E15.7/
      2  22X2HU E15.7,3H *E15.7/41X1H*/41X1H*)
C
      REWIND 3
      REWIND 4
      READ TAPE 9,ARRAY,XMACH,TOPRM,POPRM,UI,T2T1,P2P1,U2U1,NU,RNOSE
      1  ,P3P2
      CALL PAGE1 (ARRAY)
      EPSLN = 0.
      SOLAR = 0.
      DELKSI = .0005
      IMAX = 2000
      G = 0.
      IFRQ = 20
      IT = 11
      DELETA = 0
      IMID = 0
      JMAX = 0
      JFRQ = 0
      KASE = 0
      IF (NU-7) 70,70,10
      IF (NU-201) 20,20,70
      10 CONTINUE
      20 CALL FLUID
      WRITE TAPE 3,XMACH,TOPRM,POPRM,QOPRM,TSTAR,PSTAR,XNOP,DELKSI,
      1  DELETA,JMAX,ARRAY
C
      WRITE OUTPUT TAPE 6,200,T1,T2,XMACH,P1,P2,U1,U2
      WRITE OUTPUT TAPE 6,99,REO
      IFRQD = 0
      JFRQD = 0
      I = 0
      J = 0
      L = 25
      30 CALL UNV
      31 IF (1) 70,32,33
      32 CALL SUB2
      GO TO 35
C
      33 CALL SUB1

```

```

          CALL TPQ
          CALL FLOPRM
C
35      DO 350 IG=1,L
          AAA(J+1,IG) = A(IG)
350      CONTINUE
          DUM1(J+1) = V
          DUM2(J+1) = T
          DUM3(J+1) = P
          TW(J+1) = G
          IF (I) 150,140,150
140      WRITE TAPE 4,V,T
150      CONTINUE
C
40      IF (I-IFRQD) 53,42,70
42      IF (KNT) 70,43,44
43      CALL PAGE1 (ARRAY)
          KNT=5
44      CALL SUB4
          KNT=KNT-1
          WRITE OUTPUT TAPE 6,108,I,J,V,T,G, (A(II),II=1,L),
          1(UX(N),N=1,5)
55      IFRQD=IFRQD+IFRQ
53      IF (I-IMAX-1) 54,60,70
54      WRITE TAPE 3,I,DUM1,DUM2,DUM3,Q,TW,AAA
          I = I+1
          GO TO 31
C
60      CONTINUE
          REWIND 2
          END FILE 3
          END FILE 4
          REWIND 3
          REWIND 4
C
          DO 1111 I=1,12000
              A(I) = 0.
1111      CONTINUE
          CALL CHAIN (IT,8)
C
70      WRITE OUTPUT TAPE 6, 100

```

REWIND 3  
CALL DUMP  
END

308JU625  
309JU625  
909JU625

```

CUNV.....2D-GENERAL
SUBROUTINE UNV

    DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

    DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
    DIMENSION XI2U(201),DUK(201),AU(400)
    DIMENSION XI2R(201),DRK(201),AR(400)
    DIMENSION XX(201),YY(201),UU(201)
    DIMENSION XACT(2),ACT(2),YACT(2)

    COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
    COMMON T,TO,TK,TE,P,P0,PK,PE,Q,Q2,QK,QF,XK,XK2,ETA,REF0
    COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,REFTA,STRK,STRKK,STRKF
    COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,F0STR,G,TSTAR
    COMMON RSTR,RSTRK,RSTRE
    COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
    COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
    COMMON NU,XI2U,DUK,AU
    COMMON NR,XI2R,DRK,AR
    COMMON XNU1,XNU2,XNU3,NBC,XNOP
    COMMON T00,P00,QS2,KASE,RNOSE,QOPRM
    COMMON XACT,ACT,YACT,P3P2
    COMMON COM

    DIMENSION AA(400),XX1(201),UU1(201)

    F0STR = 0.0
    NBC = 101
    READ TAPE 9,(XX(II),UU(II),II=1,NU)
    NU = NU
    EOP = XX(NU)
    DEL1 = 0.0
    DEL2 = 0.0
    XCHECK = XX(1)
    DO 1 II=2,NU
    K = II
    IF (XX(II)-XCHECK) 4,2,1

```

C

```

1  XCHECK = XX(II)
   GO TO 4
2  USTR = UU(K-1)
   XK2 = XX(K-1)/EOP
   XACT(1) = 2.0*XK2
   CALL TPO
   DEL1 = 2650.*SORTF(XN/(REO*P*USTR*EOP*XK2))*T
   USTR = UU(K)
   XK2 = XX(K)/EOP
   CALL TPO
   DEL2 = 2650.*SORTF(XN/(RFO*P*USTR*FOP*XK2))*T
4  CONTINUE
   WRITE OUTPUT TAPE 6.600,EOP,SOLAR,EP SLN
   WRITE OUTPUT TAPE 6.602,DEL1,DEL2
   WRITE OUTPUT TAPE 6.601,(XX(II),UU(II),II=1,NU)
   CALL SMOOTH (XX,UU,NU,12,UU1,0)
   DO 3 II=1,NU
3  XX(II) = XX(II)/EOP
   DEL1 = DEL1/EOP
   DEL2 = DEL2/EOP
   CALL SDATA (XX,UU,AU,NU,DEL1,DEL2,XX1,UU1,N2,XACT)
   YACT(1) = 1.0
   YACT(2) = P3P2
   CALL CURFIT (XACT,YACT,ACT,2.0,0.0,1.1)
   WRITE OUTPUT TAPE 6.604,(II,XX1(II),UU1(II),II=1,N2)
   NN = 2*N2-2
   DO 5 II=1,NN
5  AA(II) = AU(II)
   NU = NBC
   CALL TABINT (AA,XX1,UU1,N2,XI2U,NU,3)
   DO 20 II=1,NU
20  CALL CURVE (AU,XX1,UU1,XI2U(II),UU(II),DUK(II),N2,1)
   CONTINUE
   CALL CURFIT (XI2U,UU,AA,NU,0.0,0.2,2)
   DO 30 II=1,NU
30  CALL CURVE (AA,XI2U,UU,XI2U(II),ANY,DUK(II),NU,2)
   BETA = 1.0
   BETAK = 0.0
   ALFAK = 2.0
   ALFAE = 0.0
   BETAE = 0.0
   STRKK = 1.0
   ETA = 1.0

```

```

909JU195
909JU200
909JU205
909JU210
909JU215
909JU220
909JU225
909JU230
909JU235
909JU240
909JU245
909JU250
909JU255
909JU260
909JU265
909JU270
909JU275
909JU280
909JU285
909JU290
909JU295
909JU300
909JU305
909JU310
909JU315
909JU320
909JU325
909JU330
909JU335
909JU340
909JU345
909JU350
909JU355
909JU360
909JU365
909JU370
909JU375
909JU380
909JU385
909JU390
909JU395
909JU400
909JU405

```

```

VSTR = 0.0
USTRE = 0.0
VSTRK = 0.0
VSTRE = 0.0
RSTRE = 0.
EOC = 1.0
CALL CURFIT (XI2U,DUK,AU,NU,0.0,0.0,2.2)
FORMAT (7F10.5)
500 FORMAT (15/( 8F9.6))
501 FORMAT (8HOL(0)* =F10.6/13H0SOLAR HEAT =F12.6,2X
600 1 10HBTU/HR-F12/14H0EMMISSIVITY =F5.2)
601 FORMAT (18H1INVISCID DATA***//19X1HS18X2HU*//(2E20.7))
602 FORMAT (8HODFL-1 =F10.6,5X,7HDEL-2 =F10.6)
603 FORMAT (1H017X3HX1218X2HU*17X3HDK//((3E20.7))
604 FORMAT (9H1FIX-DATA//24X1HS18X2HU*//((15.2F20.7))
609 FORMAT (1H016X,3HX1218X2HU*17X,3HDK//((3E20.7))
C
RETURN
END

```

```

909JU410
909JU415
909JU420
909JU425
909JU430
909JU435
909JU440
909JU445
909JU450
909JU455
909JU460
909JU465
909JU470
909JU475
909JU480
909JU485
909JU490
909JU495

```

```

CTPQ.....2D-GENERAL
C  SUBROUTINE TPQ
    DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

    DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
    DIMENSION XI2U(201),DUK(201),AU(400)
    DIMENSION XI2R(201),DRK(201),AR(400)
    DIMENSION XX(201),YY(201),UU(201)
    DIMENSION XACT(2),ACT(2),YACT(2)

    COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
    COMMON T,TO,TK,TE,P,PO,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO
    COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STKK,STRKE
    COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR
    COMMON RSTR,RSTRK,RSTRE
    COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
    COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
    COMMON NU,XI2U,DUK,AU
    COMMON NR,XI2R,DRK,AR
    COMMON XNU1,XNU2,XNU3,NBC,XNOP
    COMMON T00,P00,QS2,KASE,RNOSE,QOPRM
    COMMON XACT,ACT,YACT,P3P2
    COMMON COM

    IF (XK2-XACT(1)) 8,8,5
    CALL CURVE (ACT,XACT,YACT,XK2,CHANGE,ANY,2,1)
    P00 = P0-P2P1*CHANGE
    ANY = CHANGE*(6.+CHANGE)/(1.+6.*CHANGE)
    T00 = T0-T2T1*ANY
    CONTINUE

    Q2 = USTR**2+VSTR**2
    Q = SORTF(Q2)
    QK = (USTR*USTRK+VSTR*VSTRK)/Q
    TK = -Q*QK/ SIG1

    IF (XMACH-1.0) 2,1,2
    T = 1.0
    P = 1.0

```

909JA200  
 909JA205  
 909JA210  
 909JA215  
 909JA220  
 909JA225  
 909JA230  
 909JA235  
 909JA240  
 909JA245  
 909JA250

```

XN = 1.0
GO TO 3

      2
      T = T00+(Q52-Q2)/(2.0*SIG1)
      P = P00*(T/T00)**SIG1
      XN = XN01 / ( SQRTF(T)*(1.0+XNU2/ T + XNU3/ T**2 ))
      TDNNDT = -.5+(XNU2/T+2.0*XNU3/T**2)/(1.0+XNU2/T+XNU3/T**2)

      3
      ANY = SIG1*(P2P1/T2T1)*(T/T00)**(SIG1-1.0)
      PK = ANY*TK
      RETURN
      END
  
```

```

CFLUID.....2D-GENERAL
SUBROUTINE FLUID
C
C
      DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

      DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
      DIMENSION XI2U(201),DUK(201),AU(400)
      DIMENSION XI2R(201),DRK(201),AR(400)
      DIMENSION XX(201),YY(201),UU(201)
      DIMENSION XACT(2),ACT(2),YACT(2)

      COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
      COMMON T,TO,TK,TE,P,PO,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO
      COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
      COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRE,F,FOSTR,G,GTSTAR
      COMMON RSTR,RSTRK,RSTRE
      COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
      COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
      COMMON NU,XI2U,DUK,AU
      COMMON NR,XI2R,DRK,AR
      COMMON XNU1,XNU2,XNU3,NBC,XNOP
      COMMON T00,P00,QS2,KASE,RNOSE,QOPRM
      COMMON XACT,ACT,YACT,P3P2
      COMMON COM

      SIG1 = 3.5
      IF (XMACH-1.0) 20,1,30
      T0 = 1.0
      P0 = 1.0
      QS2 = 1.0
      T2T1 = 1.0
      P2P1 = 1.0
      GO TO 3

C
      T2T1 = 1.0
      P2P1 = 1.0
      QS2 = 1.0
      GO TO 2

C

```

```

3C
C 2
QS2 = U2U1*U2U1
SIG2P = 0.0
SIG3P = 0.0
XNU1P = 1.46E-5
XNU2P = 112.0
XNU3P = 0.0
RSIG = (1.0+SIG3P*TOPRM**4)/(SIG1*(1.0+SIG2P*TOPRM**4))
TSTAR = XMACH**2*TOPRM/(1.0-RSIG)
XNOP = XNU1P*SQRTF(TOPRM)/(1.0+ XNU2P/TOPRM+XNU3P/TOPRM**2)
XNU1 = XNU1P*SQRTF(TSTAR)/XNOP
XNU2 = XNU2P/TSTAR
XNU3 = XNU3P/TSTAR**2
T0 = (SIG1-1.0)/(SIG1*XMACH**2)
P0 = T0

C 3
COM = 6.087555E-10*TSTAR**3/XNOP*EPSLN
T00 = T0*T2T1
P00 = P0*P2P1
QOPRM = 49.1*SQRTF(TOPRM*1.8)*XMACH
RE0 = 3.2794397E2*POPRM*QOPRM/(XNOP*TOPRM)
T1 = TOPRM
P1 = POPRM
U1 = QOPRM
T2 = T2T1*T1
P2 = P2P1*P1
U2 = U2U1*U1
RETURN
END

```

```

909JB200
909JB205
909JB210
909JB215
909JB220
909JB225
909JB230
909JB235
909JB240
909JB245
909JB250
909JB255
909JB260
909JB265
909JB270
909JB275
909JB280
909JB285
909JB290
909JB295
909JB300
909JB305
909JB310
909JB315
909JB320
909JB325
909JB330
909JB335

```

```

CFLOPRM...2D-GENERAL
SUBROUTINE FLOPRM
C
  DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

  DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
  DIMENSION XI2U(201),DUK(201),AU(400)
  DIMENSION XI2R(201),DRK(201),AR(400)
  DIMENSION XX(201),YY(201),UU(201)
  DIMENSION XACT(2),ACT(2),YACT(2)

  COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
  COMMON T,TO,TK,TE,P,P0,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REQ
  COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
  COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,TSTAR
  COMMON RSTR,RSTRK,RSTRE
  COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
  COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
  COMMON NU,XI2U,DUK,AU
  COMMON NR,XI2R,DRK,AR
  COMMON XNU1,XNU2,XNU3,NBC,XNOP
  COMMON T00,P00,QS2,KASE,RNOSE,Q0PRM
  COMMON XACT,ACT,YACT,P3P2
  COMMON COM

C
C
  997 U = USTR/Q
  999 V = VSTR/Q
C
  1001 A(1)=STRK
C
  1005 A(3)=U
  1007 A(4)=ALFA/(STRK*XN)
  1009 A(5)=STRK*USTR/(2.0*USTR)
  1013 A(7)=STRK*BETAK/(2.0*BETA*U**2)
  1015 A(8)=STRK*PK/(2.0*P*USTR**2)
C
  1019 A(10)=STRK*(QK/Q+BETAK/BETA)
C
  1025 A(13)=STRK*PK/P

```

```

1029 A(15)=4.*C*USTR**2*A(4)
1031 A(16)=Q2*A(4)
1033 A(17)=STRKK+STRK*BETAK/BETA-3.*O*A(5)+0.5*A(13)*
      .1(1.0 + TDNNDT/SIG1)
1037 A(19)=A(8)/A(4)
      A(20) = O.C
1044 ANY = STRK*SQRTF((EOP*XN)/(REO*P*USTR))
C
1045 A(23) = COM*ANY
      A(24) = P
1046 A(25) = ANY*T
      RETURN
      END

```

```

909JC200
909JC205
909JC210
909JC215
909JC220
909JC225
909JC230
909JC235
909JC240
909JC245
909JC250
909JC255

```

```

CSUB--1.....2D-GENERAL
C  SUBROUTINE SUB1
    DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

    DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
    DIMENSION XI2U(201),DUK(201),AU(400)
    DIMENSION XI2R(201),DRK(201),AR(400)
    DIMENSION XX(201),YY(201),UU(201)
    DIMENSION XACT(2),ACT(2),YACT(2)

    COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
    COMMON T,TO,TK,TE,P,P0,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REO
    COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
    COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRE,F,FOSTR,G,TSTAR
    COMMON RSTR,RSTRK,RSTRE
    COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
    COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
    COMMON NU,XI2U,DUK,AU
    COMMON NR,XI2R,DRK,AR
    COMMON XNU1,XNU2,XNU3,NBC,XNOP
    COMMON T00,P00,QS2,KASE,RNOSE,QOPRM
    COMMON XACT,ACT,YACT,P3P2
    COMMON COM

C
C
    FLOATI = I
    XK = FLOATI*DELKSI
    XK2 = XK**2
    STRK = XK

C
    ALFA = 2.*XK
    XKD = (XK-DELKSI)**2
    IF (KASE) 20,10,20
10  RSTRK = 0.0
    GO TO 25
20  CONTINUE
    CALL CURVE (AR,XI2R,DRK,XK2,RSTRK2,ANY,NBC,1)
    RSTRK = 2.*XK*RSTRK2
25  CONTINUE

```

2	CALL CURVE (AU,XI2U,DUK,XK2,USTRK2,ANY,NBC,1)	909JD200
	USTRK = 2* XK*USTRK2	909JD205
	IF (I) 1,2,1	909JD210
	CONTINUE	909JD215
	RSTR = 0.	909JD220
	USTR = UI	909JD225
	GO TO 3	909JD230
1	CONTINUE	909JD235
	IF (KASE) 40,30,40	909JD240
30	RSTR = 0.0	909JD245
	GO TO 45	909JD250
40	CONTINUE	909JD255
	CALL SIGMA (AR,XI2R,DRK,NBC,XKD,XK2,SUM)	909JD260
	RSTR = RSTR+SUM	909JD265
	BETA = 6.2831853*RSTR	909JD270
	BETAK = 6.2831853*RSTRK	909JD275
45	CONTINUE	909JD280
	CALL SIGMA (AU,XI2U,DUK,NBC,XKD,XK2,SUM)	909JD285
	USTR = USTR+SUM	909JD290
3	CONTINUE	909JD295
	RETURN	909JD300
	END (0) 909J6000	909JD305
	END	

```

CSUB--4.....2D-GENERAL
SUBROUTINE SUB4
C
  DIMENSION AAA(1,30),DUM1(1),DUM2(1),DUM3(1),TW(1)

  DIMENSION ARRAY(12),A(30),UX(10),SYM(10)
  DIMENSION XI2U(201),DUK(201),AU(400)
  DIMENSION XI2R(201),DRK(201),AR(400)
  DIMENSION XX(201),YY(201),UU(201)
  DIMENSION XACT(2),ACT(2),YACT(2)

  COMMON A,UX,I,J,L,DELKSI,XMACH,TOPRM,POPRM,IMAX,UI
  COMMON T,TQ,TK,TE,P,PQ,PK,PE,Q,Q2,QK,QE,XK,XK2,ETA,REQ
  COMMON ALFA,ALFAK,ALFAE,BETA,BETAK,BETAE,STRK,STRKK,STRKE
  COMMON U,USTR,USTRK,USTRE,V,VSTR,VSTRK,VSTRE,F,FOSTR,G,GTSTAR
  COMMON RSTR,RSTRK,RSTRE
  COMMON XN,SIG1,RSIG,TDNNDT,EOC,EPSLN,EOP,SOLAR,SYM,ARRAY
  COMMON P2P1,T2T1,U2U1,XX,YY,UU,NCP,RNOSE,P2,P1,T2,T1,U2,U1
  COMMON NU,XI2U,DUK,AU
  COMMON NR,XI2R,DRK,AR
  COMMON XNU1,XNU2,XNU3,NBC,XNOP
  COMMON T00,P00,QS2,KASE,RNOSE,QOPRM
  COMMON XACT,ACT,YACT,P3P2
  COMMON COM

  UX(1) = XK2
  UX(2) = 2.0*(P-P0)
  UX(3) = USTR
  UX(4) = TSTAR*T
  UX(5) = FOSTR
  UX(6) = RSTR
  UX(7) = RSTRK
  UX(8) = USTRK
  UX(9) = VSTR
  UX(10) = VSTRE
  RETURN
  END (0) 909J9000
END

```

```

909JE000
909JE005
909JE010
909JE015
909JE020
909JE025
909JE030
909JE035
909JE040
909JE045
909JE050
909JE055
909JE060
909JE065
909JE070
909JE075
909JE080
909JE085
909JE090
909JE095
909JE100
909JE105
909JE110
909JE115
909JE120
909JE125
909JE130
909JE135
909JE140
909JE145
909JE150
909JE155
909JE160
909JE165
909JE170
909JE175
909JE180
909JE185

```

```

CSDATA
C      SUBROUTINE SDATA (X,Y,A,N,DEL1,DEL2,XT,YI,N2,XACT)
C
C      DIMENSION X(1),Y(1),A(1),A1(400),XT(1),YT(1)
C      DIMENSION XACT(2)
C
C      IT1 = 1
C      IT2 = 1
C      XCHECK = X(1)
C
C      DO 10 I=2,N
C      K = I
C      IF (X(I)-XCHECK) 90,15,10
C      XCHECK = X(I)
C      CALL CURFIT (X,Y,A,N,0.0,0.0,2,2)
C      N2 = N
C      DO 11 I=1,N
C      XT(I) = X(I)
C      YT(I) = Y(I)
C      XACT(1) = X(N)*2.0
C      XACT(2) = X(N)*3.0
C      WRITE OUTPUT TAPE 6,600
C      GO TO 99
C      KK = K
C      K = K-1
C      N1 = 1
C      WRITE OUTPUT TAPE 6,601,X(K),Y(K),Y(K),Y(KK)
C      IF (K-N) 16,12,16
C      CALL CURFIT (X,Y,A1,K,0.0,0.0,2,2)
C      XP1 = X(K)-DEL1
C      IF (XP1-X(1)) 20,20,25
C      XP1 = X(1)
C      IT1 = 2
C      CALL CURVE (A1,X,Y,XP1,YP1,DYP1,K,3)
C      XACT(1) = XP1
C
C      NT = N-K
C      XP2 = X(K)+DEL2
C      XACT(2) = XP2
C      CALL CURFIT (X(KK),Y(KK),A1,NT,0.0,0.0,2,2)

```

```

909JH000
909JH005
909JH010
909JH015
909JH020
909JH025
909JH030
909JH035
909JH040
909JH045
909JH050
909JH055
909JH060
909JH065
909JH070
909JH075
909JH080
909JH085
909JH090
909JH095
909JH100
909JH105
909JH110
909JH115
909JH120
909JH125
909JH130
909JH135
909JH140
909JH145
909JH150
909JH155
909JH160
909JH165
909JH170
909JH175
909JH180
909JH185
909JH190
909JH195

```

```

C          CALL CURVE (A1,X(KK),Y(KK),XP2,YP2,DYP2,NT,3)
          IF (XP2-X(N)) 35,30,30
          IT2 = 2
          GO TO (40,50),IT1
C
          DO 45 I=1,N
          N1 = I
          IF (X(I)-XP1)42,50,50
C
          42 XT(I) = X(I)
          YT(I) = Y(I)
          45 CONTINUE
C
          50 XT(N1) = XP1
          YT(N1) = YP1
          GO TO (51,52),IT1
          51 CALL CURFIT (XT,YT,A,N1,0,0,DYP1,2,1)
          52 IA = 2*N1-1
C
          XT(N1+1) = XP2
          YT(N1+1) = YP2
C
          CALL CURFIT (XT(N1),YT(N1),A(IA),2,DYP1,DYP2,1,1)
C
          N1 = N1+1
          N2 = N1
          GO TO (55,99),IT2
C
          55 IC = 1
C
          DO 60 I=KK,N
          IF (X(I)-XP2) 60,60,56
          IC = IC+1
          N2 = N2+1
          XT(N2) = X(I)
          YT(N2) = Y(I)
          60 CONTINUE
          IA = 2*N1-1
          CALL CURFIT (XT(N1),YT(N1),A(IA),IC,DYP2,0,1,2)
C

```

```

909JH209
909JH205
909JH210
909JH215
909JH220
909JH225
909JH230
909JH235
909JH240
909JH245
909JH250
909JH255
909JH260
909JH265
909JH270
909JH275
909JH280
909JH285
909JH290
909JH295
909JH300
909JH305
909JH310
909JH315
909JH320
909JH325
909JH330
909JH335
909JH340
909JH345
909JH350
909JH355
909JH360
909JH365
909JH370
909JH375
909JH380
909JH385
909JH390
909JH395
909JH400

```

90	CONTINUE	909JH405
99	RETURN	909JH410
600	FORMAT (38HONO SHOCK-B.L. INTERACTION POINT GIVEN )	909JH415
601	FORMAT (41HOSHOCK-B.L. INTERACTION POINT GIVEN AT...	909JH420
	1 /5H0X- =E15.7,6X4HU* =E15.7/30XE15.7 )	909JH425
	END(0)921K0000	909JH430

```

C 3-D BOUNDARY LAYER INTEGRATION PROGRAM
C THIS PROGRAM REQUIRES.....
C AIR,BBB,SIDE,SUBA,VSUBC,TSUBC,SUMARY,BCDT
C JLOOP1,JLOOP2,CCDIS,TDSEQ,SIGMAI,SUMI,INJ
C
C DIMENSION IND(12),ARRAY(12)
C DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
C DIMENSION A(1,30),B(17),ZETA(22),UP(22)
C DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
C DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
C DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
C DIMENSION CNU(1,22),CK(1,22)
C DIMENSION VB(1,22),TB(1,22),SB(1,22)
C DIMENSION ZZZ(2),VV(2),AA(4)
C DIMENSION VCC(22),TCC(22),SCC(22)
C COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
C COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
C COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
C COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
C COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KLI,INDEX,JO
C COMMON VCC,TCC,QPR,TSTAR,PSTAR,QO,CNURAT,CKRAT,SCC,XNOPR
C
C EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)
C
100 FORMAT (50H0*MOUNT INPUT TAPE (SPECIFIED ON JOB REQUEST FORM) /
101 1 19H ON TAPE UNIT *B3* /17H *AND PRESS START ///1H0)
101 FORMAT (34H0*DISMOUNT TAPE ON TAPE UNIT B3--/10H AND SAVE//
1 30H *PRESS START TO TERMINATE JOB ///1H0)
200 FORMAT (13I5,IX,A6)
201 FORMAT (4E15,8)
300 FORMAT (1H1,13A6)
301 FORMAT (1H0,11X,9HMACH NO =F8.3//3X18HFREE-STREAM TEMP =F8.3//
1 15X6HPRES =F8.3//16X5HVEL =F8.3//
2 11X10HDELTA XI =F10.5//10X11HDELTA ETA =F10.5//
3 14X7HI MAX =I5//14X7HJ MAX =I5)
302 FORMAT (21H PROGRAM OPTIONS...../38X12HSTARTING I -I5/
1 14X36HNO. ITERATIONS ON STARTING PROFILE -I5/
2 16X34HPRINT FREQUENCY DURING ITERATION -I5/
3 14X36HPRINT FREQUENCY DURING INTEGRATION -I5/
4 31X19HPUNCH-OUT CONTROL -,I5/3X23HTYPE DATA FOR STARTING

```

```

5 24H(=1 COMP.,=0 INCOMP.) -I5/26X24HINTERMEDIATE PRINT-OUT --
6 15/11X39HNO. ITERATIONS BEFORE CHANGING B-ZERO -,I5/
7 16X34HJ INTERVAL (J = 0 2-DIMENSIONAL) -I5)
C
DO 707 J=1,12
707 IND(J) = 0
IO = 2000
IND(2) = 600
IND(3) = 50
IND(4) = 20
REWIND 3
REWIND 4
C
C READ AND WRITE GENERAL INPUT DATA
C
IF (SENSE LIGHT 2)700,700
700 SENSE LIGHT 1
READ TAPE 3,XMACH,TO,P0,Q0,TSTAR,PSTAR,XNOPR,DA,DB,J0,(ARRAY(I),I=
11,12)
IND(2) = IND(2)+(IND(2)-2*(IND(2)/2))
IO = IO-(IO-2*(IO/2))
FLJ0=J0
DB=1.0/FLJ0
C
CONSTANTS OF SUTHERLAND VISCOSITY LAW
C
X1=SQRTF(1.4)*XMACH*(1.0+110.3/TO)
X2=110.3/(1.4*XMACH**2*TO)
K0 = 20
ANY =K0
DC = 1.0/ANY
DC2 = 2.0*DC
TABLE1(1) = -DC
TABLE2(1) = 0.0
DO 777 N=2,11
TABLE1(N) = TABLE1(N-1)+DC2
TABLE2(N) = TABLE2(N-1)+DC2
777 CONTINUE
TABLE1(1) = 0.0
TABLE1(12) = TABLE1(11)+DC2
C

```

910J0200  
910J0205  
910J0210  
910J0215

910J0240  
910J0245  
910J0250  
910J0255  
910J0260  
910J0265  
910J0270  
910J0280  
910J  
910J0285  
910J0290  
910J0295  
910J0300  
910J0330  
910J0335  
910J0340  
910J0345  
910J0350  
910J0355  
910J0360  
910J0365  
910J0370  
910J0375  
910J0380  
910J0385  
910J0390  
910J0395  
910J0400  
910J0405  
910J0410  
910J0415

```

INB(2) = INB(3)+1
JO=JO+1
JMAX=JO
7772 KMAX = KO+2
    KMID = KMAX-1
    KLO = KO/2
    NON = 1
    KL1 = KLO+1
C
C CALCULATE ZETA ARRAY
C
    DO 4 K=1,KMAX
    ANY = K-1
    ZETA(K) = ANY*DC
    UP(K) = 1.-ZETA(K)**2
4
C
C READ INITIAL PROFILES
C
    IF (IND(8)) 10,10,20
10 CONTINUE
    CALL SHEAR (S)
    DO 50 J=1,JMAX
    READ TAPE 4,V(J,1),T(J,1)
    ZZZ(1)=0.0
    ZZZ(2)=1.0
    VV(1)=V(J,1)
    VV(2)=0.0
    CALL CURFIT (ZZZ,VV,AA,2,0.0,0.0,0.1,2)
    S(J,1)=S(1,1)
    IF (TW(J)) 30,40,30
40 WALL=T(J,1)
    GO TO 31
30 WALL=TW(J)
31 DO 80 K=2,KMID
    CALL CURVE (AA,ZZZ,VV,ZETA(K),V(J,K),DUM,2,1)
    T(J,K)=T(J,K-1)+(WALL-T(J,1))*DC
80 S(J,K)=S(1,K)
    V(J,KMAX-1) = 0.
50 CONTINUE
    GO TO 2

```

```

20 DO 1 J=1,JMAX
   READ INPUT TAPE 5,201,(V(J,K),K=1,KMAX)
   READ INPUT TAPE 5,201,(T(J,K),K=1,KMAX)
   READ INPUT TAPE 5,201,(S(J,K),K=1,KMAX)
   CONTINUE
1
C
CHECK FOR I-START
C
2 READ TAPE 3,IG
  IF (IG-IND(1)) 2,3,2
3 BACKSPACE 3
  KM = KMAX-1
C
DO 5 J=1,JMAX
  VA(J,KM) = 0.0
  TA(J,KM) = 0.
  SA(J,KM) = 0.
  VB = 0.0
  V(J,KM) = 0.0
  S(J,1) = 0.0
  CONTINUE
5
C
DA = 2.*DA
DB = 2.*DB
DC = 2.*DC
C
CHECK ON ITERATION REQUIREMENT
C
IF (IND(1)) 7,6,7
6 BO = 2.0
  IMAX = IND(2)+1
  IPRINT = IND(3)
  NO = 0
  L = 1
  GO TO 9
C
7 NO = 1
8 BO = 1.0
  IMAX = IO+1
  IPRINT = IND(4)
  IND(10) = 0

```

```

910J0610
910J0615
910J0620
910J0625
910J0630
910J0635
910J0640
910J0645
910J0650
910J0655
910J0660
910J0685
910J0690
910J0695
910J0700
910J0705
910J0710
910J0715
910J0720
910J0725
910J0730
910J0735
910J0740
910J0745
910J0750
910J0755
910J0760
910J0765
910J0770
910J0775
910J0780
910J0785
910J0790
910J0795
910J0800
910J0805
910J0810
910J0815
910J0820
910J0825
910J0830

```

```

9      IT=2
C      IT=1
999    DO 500 I=L,IMAX
      I = I
      IF (SENSE LIGHT 1) 109,108
108    IF (NO-1) 120,110,120
109    READ TAPE 3,IG,DUM3,DUM4,P,QPR,TW,A
      GO TO 120
110    READ TAPE 3,IG,DUM1,DUM2,P,QPR,TW,A
C
120    QPR = QPR*QO
      CALL JLOOP1
      CALL SIDE
      CALL JLOOP2
C
      IF (NO) 660,620,660
620    DO 650 J=1,JMAX
      DO 650 K=1,KMID
      IF (ABSF(TA(J,K))-0.000001) 650,650,660
650    CONTINUE
      GO TO 69
660    CONTINUE
C
      IF (IT-1) 52,51,52
51    IT = IPRINT
      IF (I-2) 96,53,96
53    IF (NO) 96,96,52
52    IT = IT-1
96    DO 500 J=1,JMAX
      IF (S(J,KMID)) 600,600,5000
600    CALL SUMMARY
      WRITE OUTPUT TAPE 6,610,I,J
610    FORMAT (30H SEPARATION HAS OCCURED AT I =15,
      1 4HJ = 15,1H0)
      GO TO 75
5000   CONTINUE
C
69    IF (IND(7)-3) 70,71,71
70    IF (IND(7)-NO-1) 73,71,73
C

```

```

910J0835
910J0840
910J0845
910J0850
910J0855
910J0860
910J0865
910J0870
910J0875
910J0880
910J0885
910J0890
910J0891
910J0895
910J0900
910J0905
950J0901
950J0902
950J0903
950J0907
950J0908
950J0909
910J0910
910J0915
910J0920
910J0922
910J0925
910J0930
910J0935
910J0940
910J0942
910J0945
910J0950
910J0955
910J0000
910J0005
910J0010
910J0015
910J0020

```

71	DO 72 J=1,JMAX	910J0025
	JJ = J*10	910J0030
	ANY = BCDT(JJ)	910J0035
C		910J0040
	CALL DECKID (5H V 1,ANY)	910J0045
C	WRITE OUTPUT TAPE 7,201,(V(J,K),K=1,KMAX)	910J0050
		910J0055
	CALL DECKID (5H T 2,ANY)	910J0060
C	WRITE OUTPUT TAPE 7,201,(T(J,K),K=1,KMAX)	910J0065
		910J0070
	CALL DECKID (5HPHI 3,ANY)	910J0075
72	WRITE OUTPUT TAPE 7,201,(S(J,K),K=1,KMAX)	910J0080
C	CONTINUE	910J0085
C		910J0090
	NO = NO+1	910J0095
73	NON = NON+1	910J0100
	GO TO (8,75), NO	910J0105
C		910J0110
	REWIND 4	910J0115
75	CALL CHAIN (5,8)	910J0120
	END(0) 910J0000	910J0135
		910J0140

```

SUBROUTINE SUMARY
  DIMENSION IND(12),ARRAY(12)
  DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),B(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VB(1,22),TB(1,22),SB(1,22)
  DIMENSION AB(50),AB1(50),AB2(50),AB3(50)
  DIMENSION DELU(22),DELV(22),DELUU(22),DELUV(22),DELVV(22)
  DIMENSION TT(22),ES(22),EN(22),Z(22),GAMMA(22),ZDUM(22)
  DIMENSION V1(22),T1(22),S1(22)
  DIMENSION VCC(22),TCC(22),SCC(22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KLI,INDEX,JO
  COMMON VCC,TCC,QPR,TSTAR,PSTAR,QO,CNURAT,CKRAT,SCC,XNOPR
  COMMON DELU,DELV,DELUV,DELUU,TT,LL,LL1
  COMMON AB,AB1,AB2,AB3,ES,EN,Z,GAMMA

  EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)

  100 FORMAT (//21X1HV19X,1HT17X3HPHI// (I10,3E20.7))
  101 FORMAT (4H0I =15.5H, J =14//6H ZETA8X1HS14X1HN12X4HT/T111X2HZR
  1 //11XF6.3,4E15.6))
  102 FORMAT (4H0V =E16.7,6H T =E16.7,6H P =E16.7,6H G =E16.7//
  1 (5(5X1HA12,1H=E15.7)))
  103 FORMAT (5H0 I =15.5X3HJ =13//)
  104 FORMAT (110,1P3E20.7)
  110 FORMAT (13,0PF12.7,1PE13.6,1PE15.7,1PE13.5,0PF11.7,0PF12.8,
  1 1PE13.6,1P3E13.5)
  115 FORMAT (3H K,6X1HV,10X1HT,11X3HPHI,13X2HMU,9X1HS,
  1 10X1HN,14X1H2,10X5HDT/DZ,9X5HDS/DZ,9X5HDN/DZ)
  120 FORMAT (8H0DELS =1PE12.5,4X7HDELN =1PE12.5,4X7HDELS =
  1 1P12.5,4X7HDELS =1PE12.5,4X7HDELN =1PE12.5,8H DELU =
  2 1P12.5,4X7HDELV =1PE12.5,4X7HDELU =1PE12.5,4X7HDELUV =

```

```

910J9000
910J9005
910J9010
910J9015
910J9020
910J9025
910J9030
910J9035
910J9040
910J9045
910J9050
910J9055
910J9060
910J9065
910J9076
910J9070
910J9075
910J9080
910J9085
910J9090
910J9101
910J9095
910J9100
910J9105
910J9110
910J9115
910J9120
910J9125
910J9130
910J9135
910J9140
910J9145
910J9150
910J9155
910J9160
910J9165
910J9170
910J9175
910J9180
910J9185

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```

C          3  1PE12.5,4X,7HDELVV =1PE12.5//)
          J=J
          CALL PAGE1 (ARRAY)
          IACT=I-1
          JACT=J-1
          WRITE OUTPUT TAPE 6,103,IACT,JACT
          IF (NO) 5,3,5
          1 3  WRITE OUTPUT TAPE 6,100,(K,V(J,K),T(J,K),S(J,K),K=1,KMAX)
          GO TO 15
C
          5  N=(I+J)-2*((I+4)/2)
          NN=2+N
          KO=KMAX-2
          DO 25 K=1,KMAX
          V1(K)=V(J,K)
          T1(K)=T(J,K)
          S1(K)=S(J,K)
          25 DO 26 K=NN,KO,2
          V1(K)=V1(K)+0.5*VA(J,K)
          T1(K)=T1(K)+0.5*TA(J,K)
          S1(K)=S1(K)+0.5*SA(J,K)
          26 DO 27 LL=1,KMAX
          TT(LL)=T1(LL)/T1(1)
          GAMMA(LL)=(CNU(J,LL)/S1(LL))*TT(LL)*A(J,25)
          DELU(LL)=GAMMA(LL)*(TT(LL)-UP(LL))
          DELV(LL)=GAMMA(LL)*(TT(LL)*V1(1)-V1(LL))
          CC=GAMMA(LL)*(1.0-UP(LL))
          DELU(LL)=CC*UP(LL)
          DELUV(LL)=CC*V1(LL)
          DELVW(LL)=GAMMA(LL)*(V1(1)-V1(LL))*V1(LL)
          ES(LL)=A(J,3)**2*UP(LL)+V1(1)*V1(LL)
          27 EN(LL)=A(J,3)*(V1(LL)-V1(1))*UP(LL)
          DX=DC/2.0
          CALL SIMP (DELU,0.0,1.0,DX,21,DELU,0.0,0.1)
          CALL SIMP (DELV,0.0,1.0,DX,21,DELV,0.0,0.1)
          CALL SIMP (DELU,0.0,1.0,DX,21,DELU,0.0,0.1)
          CALL SIMP (DELU,0.0,1.0,DX,21,DELU,0.0,0.1)
          CALL SIMP (DELV,0.0,1.0,DX,21,DELV,0.0,0.1)
          CALL SIMP (GAMMA(2),0.05,1.0,DX,20,ZDUM,0.0,0.0)
          Z(1)=0.0

```

```

910J9190
910J9195
910J9200
910J9205
910J9210
910J9215
910J9220
910J9225
910J9230
910J9235
910J9240
910J9245
910J9250
910J9255
910J9260
910J9265
910J9270
910J9275
910J9280
910J9285
910J9290
910J9295
910J9300
910J9305
910J9310
910J9315
910J9320
910J9325
910J9330
910J9335
910J9340
910J9345
910J9350
910J9355
910J9360
910J9365
910J9370
910J9375
910J9380
910J9385
910J9390

```

```

28 DO 28 LL=2,KMID
   Z(LL)=ZDUM(KMID-1)-ZDUM(LL-1)
29 DO 29 LL=1,KMID
   ZDUM(LL)=-Z(LL)
   CALL CURFIT (ZDUM,ES,AB2,KMID,0.0,0.0,2,2)
   CALL CURFIT (ZDUM,TT,AB1,KMID,0.0,0.0,2,2)
   CALL CURFIT (ZDUM,EN,AB3,KMID,0.0,0.0,2,2)
   DO 30 K=1,KMID
     IF (K-1) 31,32,31
32 DTZ=0.0
   DESZ=0.0
   DENZ=0.0
   WRITE OUTPUT TAPE 6,115
   GO TO 33
31 CALL CURVE (AB1,ZDUM,TT,ZDUM(K),DUMMY,DTZ,KMID,2)
   CALL CURVE (AB2,ZDUM,ES,ZDUM(K),DUMMY,DESZ,KMID,2)
   CALL CURVE (AB3,ZDUM,EN,ZDUM(K),DUMMY,DENZ,KMID,2)
33 WRITE OUTPUT TAPE 6,110,K,V1(K),T1(K),S1(K),CNU(J,K),ES(K),EN(K),
   1 Z(K)
30 CONTINUE
   C1=A(J,3)**2
   DELS=C1*DELUS+V1(1)*DELVS
   DELN=A(J,3)*(V1(1)*DELUS-DELVS)
   DELSS=V1(1)*(-A(J,3)*DELN+2.0*C1*DELUS+V1(1)*DELVS)
   1 +C1**2*DELUUS
   DELNS=C1*(DELN+A(J,3)*V1(1)*DELUUS)-A(J,3)*((C1-V1(1)**2)
   1 *DELUS+V1(1)*DELVS)
   DELNN=-A(J,3)*V1(1)*DELN+C1*(-(-V1(1)**2)*DELUUS+2.0*V1(1)
   1 *DELUS-DELVS)
   WRITE OUTPUT TAPE 6,120,DELS,DELN,DELSS,DELNS,DELNN,
   1 DELUS,DELVS,DELUUS,DELVS,DELVS
15 WRITE OUTPUT TAPE 6,102,V(J,1),T(J,1),P(J),TW(J),(II,
   1 A(J,II),II=1,30)
20 RETURN
   END

```

910J9395  
 910J9400  
 910J9405  
 910J9410  
 910J9415  
 910J9420  
 910J9425  
 910J9430  
 910J9435  
 910J9440  
 910J9445  
 910J9450  
 910J9455  
 910J9460  
 910J9465  
 910J9470  
 910J9475  
 910J9480  
 910J9485  
 910J9490  
 910J9495  
 910J9500  
 910J9505  
 910J9510  
 910J9515  
 910J9520  
 910J9525  
 910J9530  
 910J9535  
 910J9540  
 910J9545  
 910J9550  
 910J9555  
 910J9560

```

C          SUBROUTINE SIMP (Y,X1,XL,DX,NMAX,A,CON,K)
C          Y IS DIMENSIONED ARRAY OF DEPENDENT VARIABLES
C          X1 IS THE LOWER INTEGRATION LIMIT
C          XL IS THE UPPER INTEGRATION LIMIT
C          DX IS THE INTEGRATION STEP SIZE
C          A IS DIMENSIONED ARRAY FOR RUNNING INTEGRALS,A SINGLE
C             LOCATION FOR TOTAL INTEGRALS.
C          K = 0 INDICATES RUNNING INTEGRALS TO BE COMPUTED
C          K = 1 INDICATES TOTAL INTEGRAL ONLY TO BE COMPUTED
C
C          DIMENSION Y(1),A(1)
C          A(1)=CON
C          IF (XL-X1) 1,2,2
C          DX=-1.0*ABSF(DX)
C          IF (NMAX-3) 3,4,4
C          IF (K) 5,5,6
C          NDEL=0
C          NN = 2
C          KK = NMAX - 2*(NMAX/2)
C          IF (KK) 7,10,7
C          NDEL=2
C          NN=1
C          N=3
C          M=1+NDEL
C          L=M-NDEL
C          A(M)=A(L)+DX/3.0*(Y(N-2)+4.0*Y(N-1)+Y(N))
C          N=N+2
C          M=M+NDEL
C          IF (NMAX-N) 8,9,9
C          GO TO (10,11),NN
C          NN=2
C          N=4
C          YY=(3.0*Y(1)+6.0*Y(2)-Y(3))/8.0
C          M=1+NDEL/2
C          A(M)=A(1)+DX/6.0*(Y(1)+4.0*YY+Y(2))
C          GO TO 13
C          K=-1
C          RETURN
C          END (0)

```

```

941K0000
941K0005
941K0010
941K0015
941K0020
941K0025
941K0030
941K0035
941K0040
941K0045
941K0050
941K0055
941K0060
941K0065
941K0070
941K0075
941K0080
941K0085
941K0090
941K0095
941K0100
941K0105
941K0110
941K0115
941K0120
941K0125
941K0130
941K0135
941K0140
941K0145
941K0150
941K0155
941K0160
941K0165
941K0170
941K0175
941K0180
941K0185
941K0190

```

```

SUBROUTINE CURVE (A,X,Y,XP,YP,DYP,N,IT)
CURVE COMPUTES A -Y- AND/OR A -DY/DX- FOR A GIVEN -X-
C.....USING A(I) COMPUTED IN CURFIT SUBROUTINE
C  XP = A PARTICULAR VALUE OF -X- (GIVEN)
C  YP = A PARTICULAR VALUE OF -Y-
C  DYP = DY/DX AT -XP-
C  IT = EFFICIENCY CONTROL INDEX (GIVEN)
C  IT = 1 .....ONLY YP IS COMPUTED
C  IT = 2 .....ONLY DYP IS COMPUTED
C  IT = 3 .....BOTH YP AND DYP ARE COMPUTED
C  DIMENSION A(1),X(1),Y(1)
C  IF (X(1)-XP) 11,11,10
C  C1 = X(2)-X(1)
C  DYP = (Y(2)-Y(1))/C1+A(1)*C1
C  GO TO (20,16,20),IT
C  YP = Y(1)+DYP*(XP-X(1))
C  GO TO 16
C  N = N
C  IF (XP-X(N)) 13,12,12
C  N2 = 2*(N-1)
C  C1 = X(N)-X(N-1)
C  DYP = (Y(N)-Y(N-1))/C1-A(N2-1)*C1-A(N2)*C1*C1
C  GO TO (40,16,40),IT
C  YP = Y(N)+DYP*(XP-X(N))
C  GO TO 16
C  I = 1
C  I = I+1
C  IF (X(I)-XP) 14,15,15
C  K = 2*I-3
C  C1 = XP-X(I-1)
C  C2 = X(I)-XP
C  SLOPE = (Y(I)-Y(I-1))/(X(I)-X(I-1))
C  GO TO (60,70,60),IT
C  YP = Y(I-1)+(SLOPE+A(K)*C2+A(K+1)*C1*C2)*C1
C  GO TO (16,70,70),IT
C  DYP = SLOPE +A(K)*(C2-C1)+ A(K+1)*(2*C2-C1)*C1
C  RETURN
C  END

```

```

900K2000
900K2001
900K2002
900K2003
900K2004
900K2005
900K2006
900K2007
900K2008
900K2009
900K2010
900K2011
900K2012
900K2013
900K2014
900K2015
900K2016
900K2017
900K2018
900K2019
900K2020
900K2021
900K2022
900K2023
900K2024
900K2025
900K2026
900K2027
900K2028
900K2029
900K2030
900K2031
900K2032
900K2033
900K2034
900K2035
900K2036

```

```

CCURFIT      (FEB 1963)
SUBROUTINE CURFIT (X,Y,A,N,DY1,DY2,K1,K2)
C
C CONTINUOUS DERIVATIVE INTERPOLATION SUBROUTINES
CURFIT COMPUTES COEFFICIENTS OF CUBICS -- A(I)...I=1,2*N-2
C.....FOR THE WHOLE TABULATED TABLE
C X(I) = INDEPENDENT VARIABLE.....I=1,N (GIVEN)
C Y(I) = DEPENDENT VARIABLE.....I=1,N (GIVEN)
C N = LENGTH OF Y-VS-X TABLE (GIVEN)
C DY1 = 1ST OR 2ND DERIVATIVE AT LOWER END OF TABLE
C DY2 = 1ST OR 2ND DERIVATIVE AT UPPER END OF TABLE
C K1 = 1 .....DY1 = 1ST DERIVATIVE (GIVEN)
C K1 = 2 .....DY1 = 2ND DERIVATIVE (GIVEN)
C K2 = 1 .....DY2 = 1ST DERIVATIVE (GIVEN)
C K2 = 2 .....DY2 = 2ND DERIVATIVE (GIVEN)
C
C DIMENSION X(1),Y(1),A(1)
C DIMENSION B(200),C(1)
C
C THE DIMENSION C(1) MUST FOLLOW THE DIMENSION OF B
C MINIMUM DIMENSION OF B IS.....(2*N-2)
C DIMENSION OF A IS SAME AS B, BUT GIVEN IN MAIN PROGRAM
C
C CALCULATE STORAGE PROVIDED FOR B
C NUMB = XABSF(XLOC(C(1))-XLOC(B(1)))
C NRNG=NUMB/2+1
C
C N1 = N-2
C C1 = X(2)-X(1)
C IF (C1) 70,70,1
C GO TO (2,4),K1
C B(1) = 0.0
C A(1) = (DY1-(Y(2)-Y(1))/C1)/C1
C GO TO 5
C B(1) = -C1
C A(1) = -DY1/2.0
C J = 1
C
C IF (N1) 80,42,100
C IF (NRNG-N) 80,110,110
C 100

```

```

900K0000
900K0001
900K0002
900K0003
900K0004
900K0005
900K0006
900K0007
900K0008
900K0009
900K0010
900K0011
900K0012
900K0013
900K0014
900K0015
900K0016
900K0017
900K0018
900K0019
900K0020
900K0021
900K0022
900K0023
900K0024
900K0025
900K0026
900K0027
900K0028
900K0029
900K0030
900K0031
900K0032
900K0033
900K0034
900K0035
900K0036
900K0037
900K0038
900K0039

```

C <sub>110</sub>	DO 10 I=1,N1	900K0040
	K = I+1	900K0041
	J = J+1	900K0042
	C1 = X(K)-X(I)	900K0043
	C2 = X(K+1)-X(K)	900K0044
	C3 = Y(K)-Y(I)	900K0045
	C4 = Y(K+1)-Y(K)	900K0046
	C5 = C3/C1-C4/C2	900K0047
	C6 = C1/C2	900K0048
	C7 = C1*C2	900K0049
	B(J) = 1.0/(C6*(C1-B(J-1)))	900K0050
	A(J) = (C5/C2-C6*A(J-1))*B(J)	900K0051
	J = J+1	900K0052
	B(J) = 1.0/((-C1-C2)/C7-C6*B(J-1))	900K0053
	A(J) = (-C5/C7-C6*A(J-1))*B(J)	900K0054
	CONTINUE	900K0055
10		900K0056
C		900K0057
	GO TO (20,30)*K2	900K0058
20	A(J+1) = (DY2-C4/C2+C2*A(J))/(C2*(B(J)-C2))	900K0059
	GO TO 45	900K0060
30	A(J+1) = (DY2/2.0+A(J))/(-2.0*C2+B(J))	900K0061
	GO TO 45	900K0062
C		900K0063
C	STATEMENTS 42 TO 44 ARE FOR N=2 ONLY	900K0064
C		900K0065
42	C3 = K1	900K0066
	C2 = 1.0/C3	900K0067
	GO TO (43,44)*K2	900K0068
43	A(J+1) = ((Y(2)-Y(1))/C1-A(J)*C1-DY2)/(C1*C1)*C2	900K0069
	GO TO 45	900K0070
44	A(J+1) = C3*((DY2+2.0*A(1))/(4.0*C1))	900K0071
C		900K0072
45	J = 2*(N-1)	900K0073
C		900K0074
50	J = J-1	900K0075
	IF (J) 70,70,60	900K0076
60	A(J) = A(J)-B(J)*A(J+1)	900K0077
	GO TO 50	900K0078
C		900K0079
70	RETURN	900K0080

```

C 80 WRITE OUTPUT TAPE 6,50C,N,NRNG
    CALL EXIT
500 FORMAT(4HON =15,3X9HIN CURFIT/31H .....N MUST BE IN THE RANGE
    1 13HBETWEEN 2 AND15/39HC*INCREASE DIMENSION OF B IN CURFIT
    2 19HIF N IS TOO LARGE /12HOB = 2*(N-1) )
    END
900K0081
900K0082
900K0083
900K0084
900K0085
900K0086

```

```

SUBROUTINE PAGE1 (A)
C
C      DIMENSION NAME(2),X(2),A(12)
C
C      1010 FORMAT (1H1,12A6,5X2A6,5XA6,A2,5X4HPAGE13/1H )
C
C      IF (J-1962) 10,20,10
C      J = 1962
C      NPAGE = 0
C      CALL DATT (NAME,X)
C
C      20  NPAGE = NPAGE+1
C      WRITE OUTPUT TAPE 6,1010,(A(I),I=1,12),NAME(1),NAME(2),
C      1  X(1),X(2),NPAGE
C      100 RETURN
C      END
936K1000
936K1005
936K1010
936K1015
936K1020
936K1025
936K1030
936K1035
936K1040
936K1045
936K1050
936K1055
936K1060
936K1065
936K1070

```

```

FUNCTION SUMI (A1,A2,X1,X2,Y1,Y2,XP1,XP2)
SLOPE = (Y2-Y1)/(X2-X1)
X1X2 = X1*X2
C1 = Y1-SLOPE*X1-X1X2*(A1-A2*X1)
C2 = (SLOPE+A1*(X1+X2)-A2*X1*(X1+2.*X2))/2.0
C3 = (-A1+A2*(2.*X1+X2))/3.0
C4 = -A2/4.0
SUMI = (((((C4*XP2+C3)*XP2)+C2)*XP2)+C1)*XP2
1  - (((((C4*XP1+C3)*XP1)+C2)*XP1)+C1)*XP1
RETURN
END

```

```

900K4000
900K4001
900K4002
900K4003
900K4004
900K4005
900K4006
900K4007
900K4008
900K4009

```

```

SUBROUTINE MNM (X,NX,XMAX,XMIN)
  DIMENSION X(151)
  XMAX = X(1)
  XMIN = X(1)
  DO 12 I=2,NX
    IF (X(I)-XMAX) 12,12,11
    XMAX = X(I)
  CONTINUE
  DO 14 I=2,NX
    IF (X(I)-XMIN) 13,14,14
    XMIN = X(I)
  CONTINUE
  RETURN
END (O) 925K0000

```

```

910K0000
910K0005
910K0010
910K0015
910K0020
910K0025
910K0030
910K0035
910K0040
910K0045
910K0050
910K0055
910K0060
910K0065

```

```

CLINEAR
SUBROUTINE LINEAR (X,Y,N,XP,YP)
  DIMENSION X(1),Y(1)
  DO 30 I=2,N
    IP = I
    IF (XP-X(I)) 40,40,30
  CONTINUE
  YP = Y(IP-1)+(Y(IP)-Y(IP-1))*(XP-X(IP-1))/(X(IP)-X(IP-1))
  RETURN
END

```

```

919K0000
919K0001
919K0002
919K0003
919K0004
919K0005
919K0006
919K0007
919K0008

```

```

SUBROUTINE LSQD (X,Y,L,M,N,B)
DIMENSION X(20),Y(20,50),A(10,10),B(10,50),C(20,10)
10 DO 20 I=1,N
20 C(I,1)=1.0
30 DO 50 J=2,M
40 DO 50 I=1,N
50 C(I,J)=C(I,J-1)*X(I)
60 DO 100 I=1,M
70 DO 100 J=1,M
80 A(I,J)=0.0
90 DO 100 K=1,N
100 A(I,J)=A(I,J)+C(K,I)*C(K,J)
105 DO 150 J=1,L
110 DO 150 I=1,M
120 B(I,J)=0.0
130 DO 150 K=1,N
150 B(I,J)=B(I,J)+C(K,I)*Y(K,J)
170 CALL MATINV (A,M,B,L,DETERM)
210 RETURN
END

```

```

902K0000
902K0001
902K0002
902K0003
902K0004
902K0005
902K0006
902K0007
902K0008
902K0009
902K0010
902K0011
902K0012
902K0013
902K0014
902K0015
902K0016
902K0017
902K0018

```

```

1      SUBROUTINE SIGMA (A,X,Y,N,XL,XU,SUM)
2      DIMENSION A(1),X(1),Y(1)
3      SUM = 0.0
4      IF (XU-XL) 1,21,2
5      WRITE OUTPUT TAPE 6,100,XL,XU
6      CALL EXIT
7      K = N
8      IF (X(K)-XU) 6,5,4
9      K = K-1
10     GO TO 3
11     K = K-1
12     L = N
13     IF (X(L)-XL) 9,9,8
14     L = L-1
15     GO TO 7
16     IF (K-L-1) 10,19,17
17     IA = 2*L-1
18     IB = 2*L
19     SUM = SUM1 (A(IA),A(IB),X(L),X(L+1),Y(L),Y(L+1),XL,XU)
20     GO TO 21
21     II = L+1
22     IJ = K-1
23     DO 18 I=II,IJ
24     IA = 2*I-1
25     IB = 2*I
26     SUMP = SUM1 (A(IA),A(IB),X(I),X(I+1),Y(I),Y(I+1),X(I),X(I+1))
27     SUM = SUM+SUMP
28     IA = 2*L-1
29     IB = 2*L
30     SUM1 = SUM1 (A(IA),A(IB),X(L),X(L+1),Y(L),Y(L+1),XL,X(L+1))
31     IA = 2*K-1
32     IB = 2*K
33     SUM2 = SUM1 (A(IA),A(IB),X(K),X(K+1),Y(K),Y(K+1),X(K),XU)
34     SUM = SUM+SUM1+SUM2
35     FORMAT (32HOERROR IN THE INTEGRATION LIMITS /
36     19H X(L) =E15.6,7H X(U) = E15.6/
37     237H .....X(L) IS LARGER THAN X(U)..... )
38     RETURN
39     END

```

	SUBROUTINE YDY (X1,Y1,X2,Y2,A,K,XP,YP,DYP,IT,DX)	910J
	DIMENSION A(1)	
	C1 = XP-X1	
	C2 = X2-XP	
	SLOPE = (Y2-Y1)/(X2-X1)	
	GO TO (60,70,60),IT	
60	YP = Y1+(SLOPE+A(K)*C2+A(K+1)*C1*C2)*C1	
70	GO TO (80,70,70),IT	
	DYP = SLOPE + A(K)*(C2-C1)+A(K+1)*(C2+C2-C1)*C1	
	DYP=DYP*DX	910J
80	RETURN	
	END	

```

SUBROUTINE  FILL IN (Y,DYDX,N,DX,ID,IT,DY1,DY2,K1,K2)
DIMENSION Y(1),DYDX(1),A(200),B(200)
NO = 1
N1 = N-4
XID = ID
X2 = DX*XID/2.
C1 = X2
GO TO (2,3),K1
B(1) = 0.
A(1) = (DY1-(Y(ID+1)-Y(1))/C1)/C1
GO TO 4
B(1) = -C1
A(1) = -DY1/2.0
J = 1
C2 = DX
I1 = 1
I2 = ID+1
I3 = 2
I = -1
I = I+2
J = J+1
C3 = Y(I2)-Y(I1)
I2I3 = I2+I3
C4 = Y(I2I3)-Y(I2)
C5 = C3/C1-C4/C2
C6 = C1/C2
C7 = C1*C2
B(J) = 1.0/(C6*(C1-B(J-1)))
A(J) = ( C5/C2-C6*A(J-1))*B(J)
J = J+1
B(J) = 1.0/((-C1-C2)/C7-C6*B(J-1))
A(J) = (-C5/C7-C6*A(J-1))*B(J)
C1 = DX
I1 = I2
I2 = I2+2
IF (N1-1) 10,6,5
GO TO (7,10),ID
I3 = 1
C2 = C2/2.
GO TO 5

```

```

11 GO TO (12,13),K2
12 A(J+1) = (DY2-C4/C2+C2*A(J))/(C2*(B(J)-C2))
   GO TO 14
13 A(J+1)=(DY2/2.0+A(J))/(-2.0*C2+B(J))
14 R(J+1) = 0.0
   GO TO 16
15 J = J-1
   IF (J) 17,17,16
16 A(J) = A(J)-R(J)*A(J+1)
   GO TO 15
17 CONTINUE
CALCULATION OF CURFIT COEFFICIENTS COMPLETED.....NOW, FILL IN.
  IA = 1
  IY = ID+1
  XP = 0.
  K = 1
  Y2 = Y(IY)
  DO 30 I=1,2
  CALL YDY ( , ,Y(1),X2,Y2,A,1,XP,Y(K),DYDX(K),IT,DX)
  GO TO (40,20),ID
20 XP = DX/2.0
  K = 2
  CONTINUE
30 K = K+2
  IA = IA+2
  XP = XP+DX
  X1 = X2
  Y1 = Y2
  IF (K-N) 50,45,60
45 GO TO (80,46,46),IT
46 X2 = X1+DX/2.0
  XP=X2
  Y2=Y(K)
47 NO = 2
  ITT = IT
  IF (ITT-2) 101,59,100
101 IT=2
   GO TO 59
50 X2 = X1+DX
  Y2 = Y(K+1)
59 CALL YDY(X1,Y1,X2,Y2,A,IA,XP,Y(K),DYDX(K),IT,DX)

```

910J

910J

101	GO TO (40,101),NO	
	IT=ITT	
	GO TO 80	721J
60	GO TO (70,61),ID	721J
61	K = K-1	
	IA = IA - 2	
	XP = X2	
	X1=X1-DX	
	Y1 = Y(K-2)	
	GO TO 47	721J
70	IA = IA-2	
	DYP = (Y(N)-Y(N-2))/C1-A(IA)*C1-A(IA+1)*C1*C1	
	YP = Y(N) + DYP *DX*0.5	
	GO TO (21,22,21),IT	
21	Y(K)=YP	
	GO TO (80,80,22),IT	
22	DYDX(K)=DYP*DX	910J
80	RETURN	
	END	

1	FUNCTION RCDT (I)	929K0000
2	EQUIVALENCE (NA,CNA)	929K0010
3	II = I/I0	929K0020
	IA = I-10*II	929K0030
	IC = II/I0	929K0040
	IB = II-10*IC	929K0050
	IF (IC) 1,1,3	929K0060
	IF (IB) 2,2,3	929K0070
	IB = 48	929K0090
	NA = IA+64*IB+4096*IC	929K0100
	IF (IC) 4,4,5	929K0105
R4	CNA = CNA+60000000000000	929K0110
R5	CNA = CNA+0000000606060	929K0115
	RCDT = CNA	929K0120
	RETURN	929K0130
	END	

```

C
SUBROUTINE JLOOP1
  DIMENSION IND(12),ARRAY(12)
  DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),B(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VR(1,22),TR(1,22),SB(1,22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KLI,INDEX,J0

C
EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)

C
303 FORMAT (28H)TEMPERATURE NEGATIVE AT I =15,4H J =14,4H K =13)
304 FORMAT (49H REMOVE INPUT TAPE. PRESS START FOR TERMINATION.)

C
K0=KMAX-2
DO 2000 J=1,JMAX

C
CALCULATE VALUES AT...((I-1)+(J-1)+(K-1) = EVEN
15 INDEX = (I+J)-2*((I+J)/2)
N=2-INDEX+1
DO 1000 K=N,K0+2
150 V(J,K) = V(J,K)+VA(J,K)
T(J,K) = T(J,K)+TA(J,K)
IF (T(J,K)) 180,180,151
151 S(J,K) = S(J,K)+SA(J,K)
1000 CONTINUE

C
CALCULATE VALUES AT THE WALL (I-1)+(J-1)+(K-1) = EVEN
C
IF (INDEX) 2000,16,2000
16 K = KMAX-1
C

```

```

910J1000
910J1005
910J1010
910J1015
910J1020
910J1025
910J1030
910J1035
910J1040
910J1042
910J1045
910J1050
910J1055
910J1060
910J1065
910J1070
910J1075
910J1080
910J1085
910J1090
910J1095
910J1100
910J1105
910J1110
910J1115
910J1120
910J1125
910J1130
910J1135
910J1140
910J1145
910J1150
910J1155
910J1160
910J1165
910J1170
910J1175
910J1180
910J1185
910J1190

```

```

CHECK FOR WALL THERMAL BOUNDARY CONDITIONS
C
  IF (TW(J)) 18,17,18
C
C HEAT TRANSFER RATE SPECIFIED
C
  17 T(J,K) = T(J,K)+TA(J,K)
  IF (T(J,K)) 180,180,19
  180 REWIND 2
      WRITE OUTPUT TAPE 6,303,I,J,K
      PRINT 304
      PAUSE 222
      CALL DUMP
C
C WALL TEMPERATURE SPECIFIED
C
  18 T(J,K) = TW(J)
  19 S(J,K) = S(J,K)+SA(J,K)
  2000 CONTINUE
      RETURN
      END
910J1195
910J1200
910J1205
910J1210
910J1215
910J1220
910J1225
910J1230
910J1235
910J1240
910J1245
910J1250
910J1255
910J1260
910J1265
910J1270
910J1275
910J1280
910J1285
910J1290

```

```

C
SUBROUTINE BBB
  DIMENSION IND(12),ARRAY(12)
  DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),B(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VB(1,22),TB(1,22),SB(1,22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON B0,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JO
  EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)

  K=K
  J=J
  CALL AIR
  T1=UP(K)**2
  T2=S(J,K)*DVISC
  T3=ZETA(K)*S(J,K)
  T4=S(J,K)**2/CNU(J,K)*ZT(J,K)
  T5=DC**2
  T6=A(J,6)*UP(K)
  T7=A(J,7)*V(J,K)
  B(1)=(A(J,1)*UP(K)*ZETA(K))/DA
  B(3)=T4*A(J,4)
  B(4)=B(3)/PR
  B(5)=A(J,5)*T1+V(J,K)*(T6-T7)+A(J,8)*T(J,K)*ZT(J,K)
  B(6)=(A(J,9)*T1-V(J,K)*(A(J,10)*UP(K)+A(J,11)*V(J,K))
1    -A(J,12)*T(J,K)*ZT(J,K))*ZETA(K)
  B(7)=(T(J,K)*ZT(J,K)*(A(J,13)*UP(K)+A(J,14)*V(J,K))+
1    A(J,15)*ZETA(K)**2*T4)*ZETA(K)/SIG(J,K)
  B(9)=A(J,16)*T4/SIG(J,K)*ZETA(K)/T5
  B(10)=B(4)*DCOND*ZETA(K)/T5
  B(11)=A(J,4)*(1.0-PR)/(PR*CNU(J,K))*T3/T5*ZT(J,K)

```

910J3000  
910J3005  
910J3010  
910J3015  
910J3020  
910J3025  
910J3030  
910J3035  
910J3040  
910J3045  
910J3050  
910J3055  
910J3060  
910J3065  
910J3070  
910J3075  
910J3080  
910J3085  
910J3090  
910J3095  
910J3100  
910J3105  
910J3110  
910J3115  
910J3120  
910J3125  
910J3130  
910J3135  
910J3140  
910J3145  
910J3150  
910J3155  
910J3160  
910J3165  
910J3170  
910J3175  
910J3180  
910J3185  
910J3190  
910J3195

```

B(13)=(T6-2.0*T7)*S(J,K)/(DC*ZT(J,K))
B(14)=B(1)*S(J,K)*(DVISC-DZT(J)/ZT(J,K))
B(15)=B(2)*S(J,K)*(DVISC-DZT(J)/ZT(J,K))
B(8)=- (B(3)+B(5))*S(J,K)/ZETA(K)+ZETA(K)*S(J,K)*(A(J,17)*UP(K)
1  +A(J,18)*V(J,K))-(1.0/ZT(J,K))*(DZP(J)+DCNUP(J))*(A(J,13)
2  +A(J,14)))
B(16)=S(J,K)*(B(5)*DVISC+A(J,8)*ZT(J,K))/DC+(DZT(J))*(B(5)
1 /ZT(J,K))*2-A(J,8)*CNU(J,K)*DVISC/ZT(J,K))/DC
B(17)=(A(J,4)*S(J,K)*DZT(J)/(ZT(J,K)*CNU(J,K)))/T5
B(3)=B(3)/DC
B(4)=B(4)/DC
B(5)=B(5)/DC
IF (JMAX-1) 20,10,20
10 B(2)=0.0
B(12)=0.0
B(15)=0.0
GO TO 30
20 B(2)=(A(J,2)*ZETA(K)*V(J,K))/DB
B(12)=A(J,2)*T3/DB
B(15)=B(2)*T2
30 RETURN
END
910J3200
910J3205
910J3210
910J3215
910J3220
910J3225
910J3230
910J3235
910J3240
910J3245
910J3250
910J3255
910J3260
910J3265
910J3270
910J3275
910J3280
910J3285
910J3290
910J3295
910J3300

```

910J5000  
910J5005  
910J5010  
910J5015  
910J5020  
910J5025  
910J5030  
910J5035  
910J5040  
910J5045  
910J5050  
910J5055  
910J5060  
910J5065  
910J5070  
910J5075  
910J5080  
910J5085  
910J5090  
910J5095

```

SUBROUTINE VSUBC
  DIMENSION IND(12),ARRAY(12)
  DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),B(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VB(1,22),TB(1,22),SB(1,22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JO

  EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)

  XK=K+K-2
  VC=(B(2)*VB(J,K)-XK*F*B(3)-B(6))/((XK-1.0)*B(3)-B(5))
  RETURN
END

```

C

C

910J6000  
910J6005  
910J6010  
910J6015  
910J6020  
910J6025  
910J6030  
910J6035  
910J6040  
910J6045  
910J6050  
910J6055  
910J6060  
910J6065  
910J6070  
910J6075  
910J6080  
910J6085  
910J6090  
910J6095  
910J6100  
910J6105  
910J6110  
910J6115  
910J6120  
910J6125

```

SUBROUTINE TSUBC
  DIMENSION IND(12),ARRAY(12)
  DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),B(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VB(1,22),TB(1,22),SB(1,22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JO
  EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)
  XK=K+K-2
  A1 = B(10)
  A2 = XK*B(4)-B(3)-B(5)+B(11)*SC
  A3=-BO*(B(1)+XK*B(4))*TA(J,K)-B(2)*TB(J,K)+XK*B(4)*F+B(7)
  1 +B(9)*VC**2
  TC = -A3/A2
  RETURN
END

```

```

SUBROUTINE SIDE
  DIMENSION IND(12),ARRAY(12)
  DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),B(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VB(1,22),TB(1,22),SB(1,22)
  DIMENSION VI(22),VMAX(22),T1(22),TMAX(22),S1(22),SMAX(22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON BC,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KL1,INDEX,JJ

  EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)

  DO 20 K=1,KMAX
    V1(K)=V(1,K)
    VMAX(K)=V(JMAX,K)
    T1(K)=T(1,K)
    TMAX(K)=T(JMAX,K)
    S1(K)=S(1,K)
    SMAX(K)=S(JMAX,K)
    INDEX=(1+I)-2*((1+I)/2)
    IF (IND(11)-1) 1,2,3
  1 ITT=1
    ID=2-INDEX
    N=KMAX-INDEX-1
    DO 4 K=1,KMAX
      DUM3(K)=V(1,K)
      CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,0.2,2)
    DO 5 K=1,KMAX
      V(1,K)=DUM3(K)
    DUM3(K)=T(1,K)
    CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,0.2,2)
  5 DO 6 K=1,KMAX
    T(1,K)=DUM3(K)
    DUM3(K)=S(1,K)
  6

```

	CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2.2)	910J7200
	DO 7 K=1,KMAX	910J7205
	S(1,K)=DUM3(K)	910J7210
7	DUM3(K)=V(JMAX,K)	910J7215
	CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2.2)	910J7220
	DO 8 K=1,KMAX	910J7225
	V(JMAX,K)=DUM3(K)	910J7230
8	DUM3(K)=T(JMAX,K)	910J7235
	CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2.2)	910J7240
	DO 9 K=1,KMAX	910J7245
	T(JMAX,K)=DUM3(K)	910J7250
9	DUM3(K)=S(JMAX,K)	910J7255
	CALL FILLIN (DUM3,DUM4,N,DC,ID,ITT,0.0,0.0,2.2)	910J7260
	DO 10 K=1,KMAX	910J7265
10	S(JMAX,K)=DUM3(K)	910J7270
	N=JMAX	910J7275
	ID=1+INDEX	910J7280
	ITT=2	910J7285
	DO 11 K=2,KMAX	910J7290
	CALL FILLIN (V(1,K),VB(1,K),N,DB,ID,ITT,0.0,0.0,2.2)	910J7295
	CALL FILLIN (T(1,K),TB(1,K),N,DB,ID,ITT,0.0,0.0,1.1)	910J7300
	CALL FILLIN (S(1,K),SB(1,K),N,DB,ID,ITT,0.0,0.0,1.1)	910J7305
11	ID=3-ID	910J7310
3	CONTINUE	910J7315
15	DO 21 K=1,KMAX	910J7320
	V(1,K)=V1(K)	910J7325
	V(JMAX,K)=VMAX(K)	910J7330
	T(1,K)=T1(K)	910J7335
	T(JMAX,K)=TMAX(K)	910J7340
	S(1,K)=S1(K)	910J7345
21	S(JMAX,K)=SMAX(K)	910J7350
	RETURN	910J7355
1	DO 12 K=1,KMAX	910J7360
	VB(1,K)=0.0	910J7365
	TB(1,K)=0.0	910J7370
	SB(1,K)=0.0	910J7375
	VB(JMAX,K)=0.0	910J7380
	TB(JMAX,K)=0.0	910J7385
12	SB(JMAX,K)=0.0	910J7390
	IF (JMAX-2) 15,15,16	7395
16	ID = 3-INDEX	7396

```

910J7409
910J7409
910J7410
910J7415
910J7420
910J7425
910J7430
910J7435

```

```

JJ=JMAX-2
DO 13 K=2,KMAX
DO 14 J=ID,JJ,2
VB(J,K)=V(J+1,K)-V(J-1,K)
TB(J,K)=T(J+1,K)-T(J-1,K)
SB(J,K)=S(J+1,K)-S(J-1,K)
ID=5-ID
GO TO 15
END

```

```

14
13

```

```

10 11
3
20
30
40
942K0000
942K0005
942K0010
942K0015
942K0020
942K0025
942K0030
942K0035
942K0040
942K0045
942K0050
942K0055
942K0060
942K0065
942K0070
942K0075
942K0080
942K0085
942K0090
942K0095
942K0100
942K0105
942K0110
942K0115
942K0120
942K0125
942K0130
942K0135
942K0140
942K0145
942K0150
942K0155

SUBROUTINE TABINT (A,X,Y,N,XX,M,IT)
DIMENSION A(1),X(1),Y(1),DY(101),S(101),ROOT(101),XX(1)
S(1) = 0.0
GO TO (1,3),IT
DO 2 I=1,N
DY(I) = Y(I)
GO TO 11
CALL CURFIT (X,Y,A,N,O.0,2,2)
DO 10 I=1,N
CALL CURVE (A,X,Y,X(I),ANY,DY(I),N,2)
CONTINUE
CALL MNM (X,N,XMAX,XMIN)
CALL MNM (DY,N,YMAX,YMIN)
FACTOR = (XMAX-XMIN)/(YMAX-YMIN)
CALL CURFIT (X,DY,A,N,O.0,2,2)
DO 20 I=1,N
CALL CURVE (A,X,DY,X(I),ANY,DDY,N,2)
ROOT(I) = SQRT((DDY*FACTOR)**2+1.)
CONTINUE
CALL CURFIT (X,ROOT,A,N,O.0,2,2)
DO 30 I=2,N
CALL SIGMA (A,X,ROOT,N,X(I-1),X(I),SUM)
S(I) = S(I-1)+SUM
CONTINUE
ANY = M-1
DELS = (1./ANY)*S(N)
DO 40 I=1,M
XI = I-1
ANY = XI*DELS
XX(I) = FINTER (X,S,N,ANY)
CONTINUE
RETURN
END

```

[illegible]

**A7760000**

1 IN ADDRESS

```

CLSQRD      SUBROUTINE LSQR (X,Y,L,M,N,B)
              DIMENSION X(1),Y(1),A(8,8),B(8,1),C(101,8)
              10 DO 20 I=1,N
              20 C(I,1)=1.0
              30 DO 50 J=2,M
              40 DO 50 I=1,N
              50 C(I,J)=C(I,J-1)*X(I)
              60 DO 100 I=1,M
              70 DO 100 J=1,M
              80 A(I,J)=0.0
              90 DO 100 K=1,N
              100 A(I,J)=A(I,J)+C(K,I)*C(K,J)
              105 DO 150 J=1,L
              110 DO 150 I=1,M
              120 B(I,J)=0.0
              130 DO 150 K=1,N
              150 B(I,J)=B(I,J)+C(K,I)*Y(K,J)
              170 CALL MATINV (A,M,B, L,DETERM)
              210 RETURN
                  END
902K0000
902K0002
902K0003
902K0004
902K0005
902K0006
902K0007
902K0008
902K0009
902K0010
902K0011
902K0012
902K0013
902K0014
902K0015
902K0016
902K0017
902K0018

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910J2000  
910J2005  
910J2010  
910J2015  
910J2020  
910J2025  
910J2030  
910J2035  
910J2040  
910J2045  
910J0076  
910J2050  
910J2055  
910J2060  
910J2065  
910J2070  
910J0101  
910J2075  
910J2080  
910J2085  
910J2090  
910J2095  
910J2100  
910J2105  
910J2110  
910J2111  
910J2115  
910J2120  
910J2125  
910J2130  
910J2135  
910J2140  
910J2150  
910J2155  
910J2160  
910J2161  
910J2162  
910J2163  
910J2165  
910J2170

```

SUBROUTINE JLOOP2

  DIMENSION IND(12),ARRAY(12)
  DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),B(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VB(1,22),TB(1,22),SB(1,22)
  DIMENSION VCC(22),TCC(22),SCC(22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,I7,KL1,INDEX,J0
  COMMON VCC,TCC,QPR,TSTAR,PSTAR,Q0,CNURAT,CKRAT,SCC,XNOPR

  EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)

  FORMAT (1H 1P9E13.5)
  FORMAT (1H ///,5H I = I6,5H J = I6,5H K = I6,/)
  K0=KMAX-2
  DO 4000 J=1,JMAX
    INDEX = (I+J)-2*((I+J)/2)
    J = J

  N=2+INDEX
  DO 3000 K=N,K0,2
    K = K
  CALL BBB

  VC = V(J,K+1)-V(J,K-1)
  TC = T(J,K+1)-T(J,K-1)
  SC = S(J,K+1)-S(J,K-1)
  VCC(K) = VC*DC
  TCC(K) = TC*DC
  SCC(K) = SC*DC
  VD = V(J,K+1)+V(J,K-1)-2.*V(J,K)
  TD = T(J,K+1)+T(J,K-1)-2.*T(J,K)

```

```

C          SD = S(J,K+1)+S(J,K-1)-2.*S(J,K)
C          CALCULATE FORWARD DERIVATIVES
C
C          CALL SUBA (4)
C          J = J
C          IF (IND(9)) 3000,3000,10
C          WRITE OUTPUT TAPE 6,2,1,J,K
C          WRITE OUTPUT TAPE 6,1,V(J,K),T(J,K),S(J,K),VA(J,K),TA(J,K),
C          1 SA(J,K),VB(J,K),TB(J,K),SB(J,K)
C          WRITE OUTPUT TAPE 6,1,VC,TC,SC,VD,TD,SD
C          WRITE OUTPUT TAPE 6,1,(B(11),11=1,16)
C          3000 CONTINUE
C
C          CALCULATE VALUES AT THE WALL (I-1)+(J-1)+(K-1) = ODD
C
C          IF (INDEX) 25,161,25
C          25 K = KMAX-1
C          CALL BBB
C          F = 2.0*V(J,K-1)
C          CALL VSUBC
C          IF (A(J,20)) 45,45,40
C          40 A(J,20) = 0
C          45 CONTINUE
C          A(J,29) = A(J,20)/(X1/(SQRTF(T(J,1))*(1.0+X2/T(J,1))))
C          1 *A(J,1)**2*A(J,25)*17.4545*T(J,K)/T(J,1)
C          SC = DC*(-S(J,K)-A(J,19)*CNU(J,K)*T(J,K)/S(J,K)-A(J,20))
C          SD = SC+2.*(S(J,K-1)-S(J,K))
C
C          CHECK FOR SIDE CALCULATIONS
C
C          CHECK FOR WALL THERMAL BOUNDARY CONDITIONS
C
C          30 IF (TW(J)) 37,36,37
C
C          C HEAT TRANSFER RATE SPECIFIED
C
C          36 TC = -DC*(A(J,21)+T(J,K)*(A(J,22)+A(J,23)*T(J,K)**3)/(CK(J,K)
C          1 *S(J,K)))
C          TD = TC+2.*(T(J,K-1)-T(J,K))
C          CALL SUBA (2)

```

```
C      GO TO 38
C      WALL TEMPERATURE SPECIFIED
C
37    TA(J,K) = 0.5*(TW(J)-T(J,K))
       F = 2.0*(T(J,K-1)-T(J,K))
       CALL TSUBC
       CALL SUBA (3)
C
C      CALCULATE FICTITIOUS WALL QUANTITIES
C
38    V(J,K+1) = VC+V(J,K-1)
       T(J,K+1) = TC+T(J,K-1)
       S(J,K+1) = SC+S(J,K-1)
C
161   IF (IT-1) 4000,48,4000
48    CALL SUMMARY
C
4000  CONTINUE
      RETURN
      END
```

```

C
SUBROUTINE AIR
  DIMENSION IND(12),ARRAY(12)
  DIMENSION TARLF1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),R(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VB(1,22),TB(1,22),SB(1,22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON BC,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KLI,INDEX,JO
  EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)

  K=K
  J=J
  CNU(J,K)=X1*SORTF(T(J,K))/(T(J,K)+X2)
  DVISC=(X2-T(J,K))/(2.0*T(J,K)*(X2+T(J,K)))
  CK(J,K)=4.753972
  DCOND=0.0
  SIG(J,K)=3.5
  PR=SIG(J,K)/CK(J,K)
  DZP(J)=0.0
  DZT(J)=0.0
  DCNUP(J)=0.0
  ZT(J,K)=1.0
  RETURN
END
910J8000
910J8005
910J8010
910J8015
910J8020
910J8025
910J8030
910J8035
910J8040
910J8045
910J8050
910J8055
910J8060
910J8065
910J8070
910J8075
910J8080
910J8085
910J8090
910J8095
910J8100
910J8105
910J8110
910J8115
910J8120
910J8125
910J8130
910J8135
910J8140
910J8145
910J8150
910J8155

```

```

C
SUBROUTINE SUBA (N)
  DIMENSION IND(12),ARRAY(12)
  DIMENSION TABLE1(12),TABLE2(12),TABLE4(21),TABLE5(61)
  DIMENSION A(1,30),B(17),ZETA(22),UP(22)
  DIMENSION V(1,22),VA(1,22),T(1,22),TA(1,22),S(1,22),SA(1,22)
  DIMENSION ZT(1,22),SIG(1,22),DZT(1,22),DZP(1),DCNUP(1)
  DIMENSION DUM1(1),DUM2(1),DUM3(1),DUM4(1),TW(1),P(1)
  DIMENSION CNU(1,22),CK(1,22)
  DIMENSION VB(1,22),TB(1,22),SB(1,22)
  COMMON V,T,S,VA,TA,SA,A,B,VB,TB,SB,VC,TC,SC,VD,TD,SD,TW,P
  COMMON ZETA,UP,ZT,SIG,DZT,DZP,DCNUP,CNU,CK,XK,PR,DVISC,DCOND
  COMMON BO,F,DA,DB,DC,X1,X2,PRINT,NO,NON,IG,JG,KMID,ARRAY
  COMMON DUM3,DUM4,TABLE1,TABLE2,TABLE4,TABLE5
  COMMON J,K,JMAX,KMAX,IND,I,KLO,IT,KLL,INDEX,JO

  EQUIVALENCE (DUM1,V),(DUM2,T),(DD,DUM3),(C,DUM4)

  K = K
  J = J
  XK = K+K-2
  T1 = B(3)+B(5)
  T2 = XK*B(3)
  T3 = BO*(B(1)+T2)
  GO TO (1,2,3,1),N
1  VA(J,K)=(-B(2)*VB(J,K)-T1*VC+T2*VD+B(6))/T3
  GO TO (4,4,4,2),N
2  TA(J,K) = XK*B(4)
  TA(J,K)=(-B(2)*TB(J,K)+TC*(B(11)*SC+B(10)*TC-T1)
  1 +TA(J,K)*TD+B(7)+B(9)*VC*2)/(BO*(B(1)+TA(J,K)))
  GO TO (4,3,4,3),N
3  SA(J,K)=(-B(2)*SB(J,K)+SC*(B(3)-B(5))+T2*SD+B(8)+B(12)
  1 *VB(J,K)+B(13)*VC+B(14)*TA(J,K)+B(15)*TB(J,K)+B(16)*TC)/T3
  RETURN
  END

```

```

910J4000
910J4005
910J4010
910J4015
910J4020
910J4025
910J4030
910J4035
910J4040
910J4045
910J4050
910J4055
910J4060
910J4065
910J4070
910J4075
910J4080
910J4085
910J4088
910J4089
910J4090
910J4095
910J4100
910J4105
910J4110
910J4115
910J4120
910J4125
910J4130
910J4135
910J4140
910J4145
910J4150
910J4155

```

```

CMATINV
SUBROUTINE MATINV(A,N,B,M,DETERM)
  DIMENSION IPIVOT(8),A(8,8),B(8,1),INDEX(8,2),PIVOT(8)
  EQUIVALENCE (IROW,JROW), (ICOLUMN,JCOLUMN), (AMAX, I, SWAP)

C
C
C  INITIALIZATION
  10 DETERM=1.0
  15 DO 20 J=1,N
  20 IPIVOT(J)=0
  30 DO 550 I=1,N

C
C  SEARCH FOR PIVOT ELEMENT
  40 AMAX=0.0
  45 DO 105 J=1,N
  50 IF (IPIVOT(J)-1) 60, 105, 60
  60 DO 100 K=1,N
  70 IF (IPIVOT(K)-1) 80, 100, 740
  80 IF (ABSF(AMAX)-ABSF(A(J,K))) 85, 100, 100
  85 IROW=J
  90 ICOLUMN=K
  95 AMAX=A(J,K)
  100 CONTINUE
  105 CONTINUE
  110 IPIVOT(ICOLUMN)=IPIVOT(ICOLUMN)+1
C  INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
  130 IF (IROW-ICOLUMN) 140, 260, 140
  140 DETERM=-DETERM
  150 DO 200 L=1,N
  160 SWAP=A(IROW,L)
  170 A(IROW,L)=A(ICOLUMN,L)
  200 A(ICOLUMN,L)=SWAP
  205 IF(M) 260, 260, 210
  210 DO 250 L=1, M
  220 SWAP=B(IROW,L)
  230 B(IROW,L)=B(ICOLUMN,L)
  250 B(ICOLUMN,L)=SWAP
  260 INDEX(I,1)=IROW
  270 INDEX(I,2)=ICOLUMN
  310 PIVOT(I)=A(ICOLUMN,ICOLUMN)
  320 DETERM=DETERM*PIVOT(I)

```

901K0000  
 901K0002  
 901K0003  
 901K0004  
 901K0005  
 901K0006  
 901K0007  
 901K0008  
 901K0009  
 901K0010  
 901K0011  
 901K0012  
 901K0013  
 901K0014  
 901K0015  
 901K0016  
 901K0017  
 901K0018  
 901K0019  
 901K0020  
 901K0021  
 901K0022  
 901K0023  
 901K0024  
 901K0025  
 901K0026  
 901K0027  
 901K0028  
 901K0029  
 901K0030  
 901K0031  
 901K0032  
 901K0033  
 901K0034  
 901K0035  
 901K0036  
 901K0037  
 901K0038

```

C 330 DIVIDE PIVOT ROW BY PIVOT ELEMENT
    A(I COLUMN, I COLUMN)=1.0
340 DO 350 L=1,N
350 A(I COLUMN, L)=A(I COLUMN, L)/PIVOT(I)
355 IF(M) 380, 380, 360
360 DO 370 L=1,M
370 B(I COLUMN, L)=B(I COLUMN, L)/PIVOT(I)
C 380 REDUCE NON-PIVOT ROWS
    DO 550 L1=1,N
390 IF(L1-I COLUMN) 400, 550, 400
400 T=A(L1, I COLUMN)
420 A(L1, I COLUMN)=0.0
430 DO 450 L=1,N
450 A(L1, L)=A(L1, L)-A(I COLUMN, L)*T
455 IF(M) 550, 550, 460
460 DO 500 L=1,M
500 B(L1, L)=B(L1, L)-B(I COLUMN, L)*T
550 CONTINUE
C 600 INTERCHANGE COLUMNS
    DO 710 I=1,N
610 L=N+1-I
620 IF (INDEX(L,1)-INDEX(L,2)) 630, 710, 630
630 JROW=INDEX(L,1)
640 JCOLUMN=INDEX(L,2)
650 DO 705 K=1,N
660 SWAP=A(K, JROW)
670 A(K, JROW)=A(K, JCOLUMN)
700 A(K, JCOLUMN)=SWAP
705 CONTINUE
710 CONTINUE
740 RETURN
    END
901K0039
901K0040
901K0041
901K0042
901K0043
901K0044
901K0045
901K0046
901K0047
901K0048
901K0049
901K0050
901K0051
901K0052
901K0053
901K0054
901K0055
901K0056
901K0057
901K0058
901K0059
901K0060
901K0061
901K0062
901K0063
901K0064
901K0065
901K0066
901K0067
901K0068
901K0069

```

```

C          SUBROUTINE SMOOTH (X,Y,N,LAPS,YSMOTH,IT)
C          DIMENSION X(1),Y(1),YSMOTH(1),XX(6),YY(6),B(3),YD(101)
C          X = INDEPENDENT VARIABLE --- (INPUT ARRAY)
C          Y = DEPENDENT VARIABLE --- (INPUT ARRAY)
C          LAPS = NO. OF TIMES THE TABLE TO BE SMOOTHED
C          YSMOTH = SMOOTHED Y --- (OUTPUT ARRAY)
C          IT = PRINT CONTROL*****
C          0 .... NO PRINTOUT
C          1 .... PRINT COMMENT WHEN A POINT WAS CONSIDERED WILD
C
C          NN = N-1
C          YSMOTH (N) = Y(N)
C          YSMOTH (1) = Y(1)
C          NOMAX = 3*N*LAPS
C          IF (N-7) 1,93,93
C          WRITE OUTPUT TAPE 6,600,N
C          GO TO 90
C          DO 94 J=1,N
C          YD(J) = Y(J)
C          DO 80 K=1,LAPS
C          NO = 0
C          L = 2
C          CONTINUE
C          DO 70 I=L,NN
C          NO = NO+1
C          IF (NO-NOMAX) 95,95,90
C          CONTINUE
C          INDEX = I-3
C          IF (INDEX-1) 4,8,5
C          INDEX = 1
C          GO TO 8
C          IF (INDEX-N+6) 8,8,6
C          INDEX = N-6
C          CONTINUE
C          JT = 0
C          JP = INDEX
C          DO 20 J=1,7
C          IF (JP-1) 10,20,10
C          JT = JT+1
C          XX(JT) = X(JP)
C          YY(JT) = YD(JP)
C
C          1
C          93
C          94
C          2
C          3
C          95
C          4
C          5
C          6
C          8
C          10

```

```

904K0000
904K0005
904K0010
904K0015
904K0020
904K0025
904K0030
904K0035
904K0040
904K0045
904K0050
904K0055
904K0060
904K0065
904K0070
904K0075
904K0080
904K0085
904K0090
904K0095
904K0100
904K0105
904K0110
904K0115
904K0120
904K0125
904K0130
904K0135
904K0140
904K0145
904K0150
904K0155
904K0160
904K0165
904K0170
904K0175
904K0180
904K0185
904K0190
904K0195

```

```

20      JP = JP+1
      CALL LSQB (XX,YY,1,3,6,B)
      SUM = 0.
      JP = INDEX
      DO 50 J=1,7
      VALUE = ((B(3)*X(JP))+B(2))*X(JP)+B(1)
      IF (JP-1) 40,30,40
30      CHECK = ABSF(YD(JP)-VALUE)
      POINT = VALUE
      GO TO 50
40      SUM = SUM+(VALUE-YD(JP))**2
50      JP = JP+1
      DDD = SQRTF(SUM/6.)*3.0
      IF (DDD-CHECK) 55,70,70
55      IF (IT) 60,65,60
60      WRITE OUTPUT TAPE 6,601,1,X(I),Y(I),POINT
65      YD(I) = POINT
      Y(I) = POINT
      L = I-3
      IF (L-1) 2,2,3
70      YSMOTH(I) = POINT
      DO 80 J=1,N
80      YD(J) = YSMOTH(J)
90      RETURN
600      FORMAT (36H0TABLE TOO SMALL FOR SMOOTHING..... /
1      10H .....N =12,35H, *THERE MUST BE 7 OR MORE POINTS*)
601      FORMAT (24H0A POINT WAS WILD AT I =13,5H, X =E14.6/
1      1 4H Y =E14.6,26H...HAS BEEN CHANGED TO ...E14.6)
      END

```

```

904K0200
904K0205
904K0210
904K0215
904K0220
904K0225
904K0230
904K0235
904K0240
904K0245
904K0250
904K0255
904K0260
904K0265
904K0270
904K0275
904K0280
904K0285
904K0290
904K0295
904K0300
904K0305
904K0310
904K0315
904K0320
904K0325
904K0330
904K0335

```

SUBROUTINE SHEAR (X)  
 DIMENSION X(22)

C

X(1) = 0.0  
 X(2) = 1.987  
 X(3) = 3.353  
 X(4) = 4.415  
 X(5) = 5.257  
 X(6) = 5.922  
 X(7) = 6.441  
 X(8) = 6.832  
 X(9) = 7.112  
 X(10) = 7.293  
 X(11) = 7.386  
 X(12) = 7.401  
 X(13) = 7.347  
 X(14) = 7.231  
 X(15) = 7.062  
 X(16) = 6.849  
 X(17) = 6.600  
 X(18) = 6.324  
 X(19) = 6.032  
 X(20) = 5.735  
 X(21) = 5.450  
 X(22) = 5.190  
 RETURN  
 END

950JNN00  
 950JNN01  
 950JNN02  
 950JNN03  
 950JNN04  
 950JNN05  
 950JNN06  
 950JNN07  
 950JNN08  
 950JNN09  
 950JNN10  
 950JNN11  
 950JNN12  
 950JNN13  
 950JNN14  
 950JNN15  
 950JNN16  
 950JNN17  
 950JNN18  
 950JNN19  
 950JNN20  
 950JNN21  
 950JNN22  
 950JNN23  
 950JNN24  
 950JNN25  
 950JNN26

		SUBROUTINE SELECT (XXA,T,N,II)	950JDD00
*		LABEL	950JDD
	C	950JDD	950JDD01
		DIMENSION B(10,100),XXA(10),XX1(10)	950JDD02
		EQUIVALENCE (XX1(10),NPONT)	950JDD03
	C		950JDD04
		IF (T) 10,10,20	950JDD05
	10	K = 3	950JDD06
		GO TO 30	950JDD07
	20	K = 4	950JDD08
	C		950JDD09
	30	IF (II) 35,33,31	950JDD10
	31	BACKSPACE K	950JDD11
	33	BACKSPACE K	950JDD12
		READ TAPE K,B	950JDD13
	C		950JDD14
	35	DO 40 I=1,100	950JDD15
		CALL DMOVE (XX1,B(1,I))	950JDD16
		IF (NPONT-N) 40,50,40	950JDD17
	40	CONTINUE	950JDD18
	C		950JDD19
	50	CALL DMOVE (XXA,XX1)	950JDD20
		RETURN	950JDD21
		END	

```

*          SUBROUTINE STORE (B,W,K,M,ARRAY)
          LABEL
950JR      950JR
C          ROUTINE TO MOVE W-ARRAY TO B-ARRAY,
C          TO PRINT IF DESIRED, M(1)=1 ALL DATA.
C          K IS TAPE DATA GOES ON--4 FOR LOWER
C          FLOW --3 FOR UPPER FLOW.
C
C          DIMENSION B(10,100),W(10,100),M(10)
C          EQUIVALENCE (XNPT,NPT)
C
500        FORMAT (1P6E15.5,3XA6,1PE15.5)
510        FORMAT (///9X1HX,14X1HY,14X1HP,11X5HTHETA,12X3HZMU,13X1HR,
1          8X9HINDICATOR,3X1HW)
B          SHOCK1 = 436230462342
B          SHOCK2 = 646230462342
B          FIELD = 605460546054
B          BODY1 = 436022462470
B          BODY2 = 646022462470
B          SLPST = 654651632567
          CALL PAGE2 (5,ARRAY)
          WRITE OUTPUT TAPE 6,510
C
          DO 100 I=1,100
          CALL PAGE2 (1,ARRAY)
          CALL DMOVE (B(1,I),W(1,I))
          XNPT = B(7,I)
          IF (NPT-12345) 90,200,90
          CONTINUE
90          IF (NPT) 10,20,30
          IF (NPT+2)50,40,40
10          AF = FIELD
20          GO TO 60
          IF (NPT-1) 34,34,38
30          AF = SHOCK1
34          GO TO 65
          IF (NPT-11) 39,34,39
38          AF = SHOCK2
39          WRITE OUTPUT TAPE 6,500,(B(J,I),J=1,6),AF,B(8,I)
65

```

```

C      40      GO TO 100
      44      IF (NPT+1) 48,44,44
      48      AF = BODY1
      50      GO TO 60
      60      AF = BODY2
      70      GO TO 60
      80      AF = SLPST
      90      CONTINUE
      100     WRITE OUTPUT TAPE 6,500,(B(J,I),J=1,6),AF
      110     CONTINUE
      120     WRITE TAPE K,B
      130     RETURN
      140     END
950JR038
950JR039
950JR040
950JR041
950JR042
950JR043
950JR044
950JR045
950JR046
950JR047
950JR048
950JR049
950JR050
950JR051

```

```

SUBROUTINE XY (X1,Y1,X2,Y2,X3,Y3,X4,Y4,X,Y)
  LABEL
  * 950JS
  C
  C ROUTINE TO INTERSECT TWO STRAIGHT LINES
  C IF X2 = 0 Y2 = SLOPE AT X1,Y1.
  C IF X4 = 0 Y4 = SLOPE AT X3,Y3.
  C
  C IF (X2) 10,20,10
  C 10 S1 = (Y2-Y1)/(X2-X1)
  C GO TO 30
  C
  C 20 S1 = Y2
  C 30 IF (X4) 40,50,40
  C 40 S2 = (Y3-Y4)/(X3-X4)
  C GO TO 60
  C
  C 50 S2 = Y4
  C 60 X = (S1*X1-S2*X3+Y3-Y1)/(S1-S2)
  C Y = Y1+(X-X1)*S1
  C
  C RETURN
  C END

```

```

950JS000
950JS
950JS001
950JS002
950JS003
950JS004
950JS005
950JS006
950JS007
950JS008
950JS009
950JS010
950JS011
950JS012
950JS013
950JS014
950JS015
950JS016
950JS017
950JS018
950JS019

```

```

SUBROUTINE PAGE2 (J,A)
  LABEL
  950JT
C
C   J = -1 READ HEADING CARD.
C   J = 0 EJECT PAGE.
C   J = N N IS NUMBER OF LINES TO BE PRINTED.
C
C   DIMENSION X(2),A(12),NAME(2)
C
C   1010 FORMAT (1H1,12A6,5X2A6,5XA6,A2,5X4HPAGE,I3//)
C
C   IF (J) 10,20,30
C
C   10  NPAGE = 0
C
C   20  CALL DATT (NAME,X)
C       NPAGE = NPAGE+1
C       NLINE = 40
C       WRITE OUTPUT TAPE 6,1010,(A(I),I=1,12),NAME(1),NAME(2),
1      X(1),X(2),NPAGE
C       GO TO 100
C
C   30  NLINE = NLINE-J
C       IF (NLINE) 20,20,100
C
C   100 RETURN
C       END

```

```

C          2-D BODY POINT ROUTINE
*          LABEL
950JU      SUBROUTINE BODYPT (T,XX1,XX2,XX3,C1,M1)
C
C          T = 1.  - - INTERSECT BODY WITH RIGHT RUNNING CHAR.
C          T = -1. - - INTERSECT BODY WITH LEFT RUNNING CHAR.
C          XX1(10) IS THE BASE POINT ON BODY.
C          XX2(10) IS THE BASE POINT IN THE FIELD.
C          XX3(10) IS THE NEW BODY POINT.
C          GAMMA(13) IS AN ARRAY OF FUNCTIONS OF GAMMA.
C          M1 IS A CONTROL INDICATOR .
C          = 1 MEANS CALCULATION IS COMPLETE.
C          = 2 MEANS THERE IS AN ERROR IN THE CALCULATION.
C
C          DIMENSION XX1(10),XX2(10),XX3(10)
C
C          23  FORMAT (//39H T34,T35, OR P3/R3 IS ZERO. THE MACH .
133HNUMBER FOR THIS APPROXIMATION IS ,1PE16.5,1H,///)
C          X1 = XX1(1)
C          Y1 = XX1(2)
C          P1 = XX1(3)
C          TH1 = XX1(4)
C          ZMU1 = XX1(5)
C          R1 = XX1(6)
C          X2 = XX2(1)
C          Y2 = XX2(2)
C          P2 = XX2(3)
C          TH2 = XX2(4)
C          ZMU2 = XX2(5)
C
C          10  IF (NN-4321) 10,20,10
NN = 4321
C7 = (C1-1.0)/C1
C12 = 2.0/(1.-C1)
C
C          CALCULATE THE FIRST APPROXIMATION OF X3 ON THE
C          BODY. THIS X3 IS USED BY SUBROUTINE LOCATE TO PICK
C          THE COEFFICIENTS OF THE APPROPRIATE CUBIC FOR THIS
C          PART OF THE BODY.

```

```

C 20      T1 = SIN((TH1)/COS((TH1))
          T2 = SIN((TH2-T*ZMU2)/COS((TH2-T*ZMU2))
          X3 = (Y2-Y1+X1*T1-X2*T2)/(T1-T2)
          CALL LOCATE (1,T,ITT,AC,BC,CC,DC,X3)
401      ARG4 = ZMU2
          ARG6 = TH2
          K = 0
          P3L = 1000.0
          T11 = P2
          R3 = R1
          GO TO 403
402      ARG4 = 0.5*(ZMU2+ZMU3)
          ARG6 = 0.5*(TH2+TH3)
          T11 = 0.5*(P2+P3)
403      ARG2 = ARG6 - T*ARG4
          T10 = SIN((ARG6))
          T8 = COS((ARG4))
          T9 = SIN((ARG4))
          T3 = COS((ARG2))
          T4 = SIN((ARG2))
          T81 = T4/T3
          T82 = CC -T81
          T33 = DC-Y2+X2*T81

C          THE FOLLOWING LOOP CALCULATES THE INTERSECTION
C          OF A CHARACTERISTIC WITH THE BODY. THE METHOD
C          USED IS NEWTON ITERATION.
C
404      DO 431 I=1,20
          POL = ((AC*X3+BC)*X3+T82)*X3+T33
          POLP = (3.*AC*X3+2.*BC)*X3+T82
          IF (ABS((POLP)) - .00000001) 405, 405, 430
          DPOL = POL/POLP
          X3 = X3- DPOL
          IF (ABS((DPOL)) - MAX1F(.00001 * X3, .00001)) 405, 405, 431
          CONTINUE
430      Y3 = Y2+ T81*(X3-X2)
431
405      CALCULATE FLOW DIRECTION (TH3), PRESSURE (P3),
          MACH ANGLE (ZMU3).
C
C
C

```

```

950JU038
950JU039
950JU040
950JU041
950JU042
950JU043
950JU044
950JU045
950JU046
950JU047
950JU048
950JU049
950JU050
950JU051
950JU052
950JU053
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950JU055
950JU056
950JU057
950JU058
950JU059
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950JU062
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950JU064
950JU065
950JU066
950JU067
950JU068
950JU069
950JU070
950JU071
950JU072
950JU073
950JU074
950JU075
950JU076
950JU077
950JU078

```

```

C 407 T18 = 1.0/(T8*T9)
      TH3 = ATANF((3.*AC*X3+2.*BC)*X3+CC)
      P3 = P2+C1*T11*(T*T18*(TH3-TH2))
373 T30 = P3/R3
      IF (T30) 406,406,375
375 T30 = C12*(1.-T30*(-C7)) -1.
      IF (T30-.04) 406,406,377
406 M1 = 2
      WRITE OUTPUT TAPE 6,23
      GO TO 380
377 ZMU3 = ATANF(SQRTF(1.0/T30))
C
C      CONVERGENCE TEST (DIFFERENCE IN PRESSURE
C      ON TWO SUCCESSIVE APPROXIMATIONS MUST BE
C      LESS THAN .001 OF CURRENT PRESSURE).
C
      IF (ABSF(P3-P3L)-.001*P3) 378,378,379
379 P3L=P3
      IF (K-100) 1,1,378
1 K = K +1
      GO TO 402
378 M1 = 1
C      X3 MUST BE CHECKED BY SUBROUTINE LOCATE
C      TO MAKE SURE THAT THE COEFFICIENTS USED IN
C      THE CALCULATION ARE THE RIGHT COEFFICIENTS.
C
      CALL LOCATE (O,T,ITT,AC,BC,CC,DC,X3)
      IF (ITT) 380,380,401
C
380 XX3(1) = X3
      XX3(2) = Y3
      XX3(3) = P3
      XX3(4) = TH3
      XX3(5) = ZMU3
      XX3(6) = R3
      XX3(7) = XX1(7)
      RETURN
      END

```

950JU079  
 950JU080  
 950JU081  
 950JU082  
 950JU083  
 950JU084  
 950JU085  
 950JU086  
 950JU087  
 950JU088  
 950JU089  
 950JU090  
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 950JU092  
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 950JU106  
 950JU107  
 950JU108  
 950JU109  
 950JU110  
 950JU111  
 950JU112  
 950JU113  
 950JU114  
 950JU115

CCUBIC	*	950JV0000	
		950JV	
		950JV001	
		950JV002	
		950JV003	
		950JV004	
		950JV005	
		950JV006	
		950JV007	
		950JV008	
		950JV009	
		950JV010	
		950JV011	
		950JV012	
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		950JV016	
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		950JV018	
		950JV019	
		950JV020	
		950JV021	
		950JV022	
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		950JV024	
		950JV025	
		950JV026	
		950JV027	
		950JV028	
		950JV029	
		950JV030	
		950JV031	
		950JV032	
		950JV033	
		950JV034	
		950JV035	
		950JV036	
		950JV037	

```

SUBROUTINE CUBIC (X,Y,IND,N,DY1,DY2,ACI)
DIMENSION X(1),Y(1),IND(1)
DIMENSION XX(50),YY(50),A(100),ACI(6,1)
DDY1 = DY1
IL = 1
K = 0
DO 60 I=1,N
K = K+1
XX(K) = X(I)
YY(K) = Y(I)
IF (I-N) 5,20,5
IF (IND(I)) 60,60,30
20 DDY2 = DY2
IF (K-2) 60,60,40
30 SLOPE = (Y(I+1)-Y(I)) / (X(I+1)-X(I))
IF (I-1) 35,50,35
35 DDY2 = SLOPE
40 IA = 2*IL-1
CALL CURFIT (XX,YY,A(IA),K,DDY1,DDY2,1,1)
IF (I-N) 50,60,50
50 IA = 2*I-1
A(IA) = 0.
A(IA+1) = 0.
IL = I+1
K = 0
DDY1 = SLOPE
CONTINUE
NN = N-1
DO 70 I=1,NN
IA = 2*I-1
A1 = A(IA)
A2 = A(IA+1)
X1 = X(I)
X2 = X(I+1)
Y1 = Y(I)
Y2 = Y(I+1)
SLOPE = (Y2-Y1) / (X2-X1)

```

```

950JV038
950JV039
950JV040
950JV041
950JV042
950JV043
950JV044
950JV045
950JV046

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X1X2 = X1*X2
ACI(6,I) = X2
ACI(5,I) = Y1-SLOPE*X1-X1X2*(A1-A2*X1)
ACI(4,I) = SLOPE+A1*(X1+X2)-A2*X1*(X1+2.*X2)
ACI(3,I) = -A1+A2*(2.*X1+X2)
ACI(2,I) = -A2
ACI(1,I) = X1
CONTINUE
RETURN
END

```

70

```

C      2-D FIELD POINT CALCULATION
*      LABEL
950JW SUBROUTINE FDPT (XX1,XX2,XX3,GAMMA,M1)
C
C      DIMENSION XX1(10),XX2(10),XX3(10)
C
22  FORMAT(25H Y3 IS ZERO OR NEGATIVE.)
23  FORMAT(21H T34 OR T35 IS ZERO.)
24  FORMAT(23H RAD OR P3/R3 IS ZERO.)
C
C1 = GAMMA
RRRR = 0.0
X1 = XX1(1)
Y1 = XX1(2)
P1 = XX1(3)
TH1 = XX1(4)
ZMU1 = XX1(5)
R1 = XX1(6)
X2 = XX2(1)
Y2 = XX2(2)
P2 = XX2(3)
TH2 = XX2(4)
ZMU2 = XX2(5)
R2 = XX2(6)
C
C7 = (C1-1.0)/C1
C12 = 2.0/(1.0-C1)
CT1 = (P1-P2)/C1
CT2 = TH1-TH2
ARG3 = ZMU1
ARG5 = TH1
ARG4 = ZMU2
ARG6 = TH2
T35 = Y1
T34 = Y2
NPT3 = 0
T11 = P1
T12 = P2
T7 = SIN(ARG5)

```

```

950JW000
950JW
950JW001
950JW002
950JW003
950JW004
950JW005
950JW006
950JW007
950JW008
950JW009
950JW010
950JW011
950JW012
950JW013
950JW014
950JW015
950JW016
950JW017
950JW018
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950JW021
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950JW025
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950JW027
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950JW029
950JW030
950JW031
950JW032
950JW033
950JW034
950JW035
950JW036
950JW037

```



```

115 = T12/T11
116 = 1.0/(T5*T6)
118 = 1.0/(T8*T9)
Y3 = (X2-Y2*T13-X1+Y1*T14)/(T14-T13)
IF (Y3) 1,1,2
M1 = 2
WRITE OUTPUT TAPE 6,22
GO TO 380
X3 = X1 + (Y3-Y1)*T14
IF (ABS(F(P1-P2) - .000001) 10,10,11
10 IF (ABS(F(TH1-TH2) - .000001) 12,12,11
12 P3 = P1
TH 3 = TH1
ZMU3 = ZMU1
R3 = R1
W3 = W1
GO TO 378
11 T35 = 0.5*(Y1+Y3)
T34 = 0.5*(Y2+Y3)
IF (T35) 366,650,366
366 IF (T34) 367,650,367
650 M1 = 2
WRITE OUTPUT TAPE 6,23
GO TO 380

C COMPLETE CALC. OF COEFS. OF COMP. EQS. CALCULATE FLOW DIRECTION
C AND PRESSURE.
C
C 367 T17 = T7/(T5*T1*T35)
T19 = T10/(T8*T3*T34) *RRRR
T20 = (X3-X1)*RRRR
T21 = X3-X2
TH3 = TH2 + (C11/T11 + T16*CI2 - T17*T20 + T19*T15*T21)/(T16 + T15*T18)
P3 = P2 + C1*T12*(T18*(TH3-TH2) - T19*T21)

C PREPARE FACTOR RR USED IN CALC. OF STAG. PRESSURE RATIO. OF TWO
C VALUES FOR RR, CHOOSE VALUE NEAREST 1/2. THEN CALC. STAG. PRESSURE
C RATIO FOR PT. 3.
C
C T29 = SINF(TH3)/COSF(TH3) + T25
D = 0.5*((T26*T29 - 2.0*T27)/T24 - T21)

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950JW079  
 950JW080  
 950JW081  
 950JW082  
 950JW083  
 950JW084  
 950JW085  
 950JW086  
 950JW087  
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 950JW113  
 950JW114  
 950JW115  
 950JW116  
 950JW117  
 950JW118  
 950JW119

```

E = (-T21*T29-2.0*(Y2-Y3))*T26/T24
RAD = D**2-E
IF (RAD) 370,368,368
370 M1 = 2
WRITE OUTPUT TAPE 6,24
1111 FORMAT (1P6E15.5)
WRITE OUTPUT TAPE 6,1111,(XX1(I),I=1,6)
WRITE OUTPUT TAPE 6,1111,(XX2(I),I=1,6)
CALL DUMP
368 RAD = SQRTF(RAD)
RR1 = (-D+RAD)/T26
RR2 = (-D-RAD)/T26
RRR = SINF(TH3)/COSF(TH3)
RRF = -((X2-X3)*RRR-Y2+Y3)/((X1-X2)*RRR-Y1+Y2)
IF (ABSF(RRF-RR1)-ABSF(RRF-RR2)) 369,371,371
369 RR = RR1
GO TO 372
371 RR = RR2
372 R3 = R2 + RR*T28
C
373 T30 = P3/R3
IF (T30) 370,370,375
375 T30 = C12*(1.-T30**(-C7)) -1.
IF (T30-.04) 374,374,377
374 M1 = 3
GO TO 380
377 ZMU3 = ATANF(SQRTF(1.0/T30))
C
379 P3L=P3
IF (KTR-100) 1017,1017,378
1017 KTR = KTR+1
GO TO 363
378 M1 = 1
380 XX3(1) = X3
XX3(2) = Y3
XX3(3) = P3
XX3(4) = TH3
XX3(5) = ZMU3
XX3(6) = R3
XX3(7) = 0.0
950JW120
950JW121
950JW122
950JW123
950JW124
950JW125
950JW126
950JW127
950JW128
950JW129
950JW130
950JW131
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950JW150
950JW151
950JW152
950JW153
950JW154
950JW155
950JW156
950JW157
950JW158
950JW159
950JW160

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950JW161

RETURN  
END



```

C 20      C6 = 2.0/(C1+1.0)
          C9 = (C1+1.0)/2.0
          DEL = AA*(STH-THIU)
          NPT3 = NPTIU
C
C      THE FOLLOWING STATEMENTS CALCULATE THE QUANTITY
C      DELIM WHICH IS THE MAXIMUM DEFLECTION ANGLE
C      POSSIBLE FOR FLOW TO REMAIN SUPERSONIC.
C      THIS ANGLE IS THEN COMPARED WITH THE DESIRED
C      TURNING ANGLE. IF THE DESIRED TURN IS TO GREAT
C      THE CALCULATION IS TERMINATED.
C
C 62      T32 = (1.0/SINF(ZMU1))**2
          WW = ATANF(SQRTF(1.0/(T32-1.0)))
          DW = -.001
          WL = WW
          SSW2 = (1.0/(4.0*T32*C1)) * (2.0*C9* T32- (3.0-C1) +
1          SQRTF(2.0*C9*(2.0*C9*T32**2-2.0*T32*(3.0-C1) + C1+9.0)))
          WLIM = ATANF(SQRTF(1.0/(1.0 /SSW2-1.0)))
          T29 = SINF(2.0*WLIM)
          T65 = COSF(2.0*WLIM)
          T66 = T32 * T29 - 2.0 * COSF(WLIM)/SINF(WLIM)
          T67 = T32 * (C1 + T65) + 2.0
          DELIM = ATANF (T66/T67)
          IF (DEL-DELIM) 905,97,97
          K = K
          T32 = SQRTF(T32)
          WRITE OUTPUT TAPE 6,22,T32,DEL,DELIM,X1,Y1,P1,TH1,ZMU1
          M1 = 2
          RETURN
C
C      THE FOLLOWING LOOP IS AN ITERATION ON THE SHOCK
C      ANGLE (WW).
C
C 905      DO 60 K = 1,100
C 903      WW = WW+DW
          T29 = SINF(2.0*WW)
          T65 = COSF(2.0*WW)
          T66 = T32*T29 -2.0*COSF(WW)/SINF(WW)
          T67 = T32*(C1 + T65) + 2.0

```

```

950JY038
950JY039
950JY040
950JY041
950JY042
950JY043
950JY044
950JY045
950JY046
950JY047
950JY048
950JY049
950JY050
950JY051
950JY052
950JY053
950JY054
950JY055
950JY056
950JY057
950JY058
950JY059
950JY060
950JY061
950JY062
950JY063
950JY064
950JY065
950JY066
950JY067
950JY068
950JY069
950JY070
950JY071
950JY072
950JY073
950JY074
950JY075
950JY076
950JY077
950JY078

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```

*          SUBROUTINE SLPSTM (T,XX1,XX2,XX3,C1)
          LABEL
          950JQ
C          ROUTINE TO CALCULATE A POINT ON A SLIPSTREAM.
C
C          T = 1. - - INTERSECT BODY WITH RIGHT RUNNING CHAR.
C          T = -1. - - INTERSECT BODY WITH LEFT RUNNING CHAR.
C
C          DIMENSION XX1(10),XX2(10),XX3(10)
C
C          21 FORMAT (1P4E16.5)
C          23 FORMAT (26H T34,T35 OR P3/R3 IS ZERO.)
C          RRR = 0.0
C          X1 = XX1(1)
C          Y1 = XX1(2)
C          P1 = XX1(3)
C          TH1 = XX1(4)
C          ZMU1 = XX1(5)
C          R1 = XX1(6)
C          X2 = XX2(1)
C          Y2 = XX2(2)
C          P2 = XX2(3)
C          TH2 = XX2(4)
C          ZMU2 = XX2(5)
C          P3 = XX3(3)
C          TH3 = XX3(4)
C          ZMU3 = XX3(5)
C          R3 = R1
C
C          C7 = (C1-1.0)/C1
C          C12 = 2.0/(1.-C1)
C          DO 379 I=1,20
C          T1 = (TH1+TH3)/2.
C          T1 = SIN((T1)/COSF(T1))
C          T2 = (TH2+TH3)/2.-T*(ZMU2+ZMU3)/2.
C          T2 = SIN((T2)/COSF(T2))
C          X3 = (Y2-Y1+X1*T1-X2*T2)/(T1-T2)
C          ARG4 = 0.5*(ZMU2+ZMU3)
C
          402

```

```

ARG6 = 0.5*(TH2+TH3)
T11 = 0.5*(P2+P3)
403 ARG2 = ARG6 - T*ARG4
T10 = SIN(ARG6)
T8 = COS(ARG4)
T9 = SIN(ARG4)
T3 = COS(ARG2)
T4 = SIN(ARG2)
T81 = T4/T3
405 Y3 = Y2 + T81*(X3-X2)
T34 = 0.5*(Y2 + Y3)
IF (T34) 407,406,407
406 M1 = 2
WRITE OUTPUT TAPE 6,23
GO TO 360
407 T18 = 1.0/(T8*T9)
T19 = T10/(T8*T3*T34)*RRR
P3L = P3
P3 = P2 + C1*T11*(T*T18*(TH3-TH2)-T19*(X3-X2))
373 T30 = P3/R3
IF (T30) 406,406,375
375 T30 = C12*(1.-T30**(-C7)) -1.
IF (T30-.04) 376,376,377
376 M1 = 3
GO TO 380
377 ZMU3 = ATANF(SQRTF(1.0/T30))
IF (ABSF(P3-P3L)-.001*P3) 380,380,379
379 CONTINUE
C
380 XX3(1) = X3
XX3(2) = Y3
XX3(3) = P3
XX3(4) = TH3
XX3(5) = ZMU3
XX3(6) = R3
RETURN
END
950JQ038
950JQ039
950JQ040
950JQ041
950JQ042
950JQ043
950JQ044
950JQ045
950JQ046
950JQ047
950JQ048
950JQ049
950JQ050
950JQ051
950JQ052
950JQ053
950JQ054
950JQ055
950JQ055
950JQ056
950JQ057
950JQ058
950JQ059
950JQ060
950JQ061
950JQ062
950JQ062
950JQ063
950JQ064
950JQ065
950JQ066
950JQ067
950JQ068
950JQ069
950JQ070
950JQ071

```

```

* 950JX SUBROUTINE MEET (X1,Y1,N1,X2,Y2,N2,XP,YP,DY1,DY2)
  LABEL
  DIMENSION X1(1),Y1(1),X2(1),Y2(1),A1(100),A2(100)
  DIMENSION X(21),D(21),A(40)
  XL = MAX1F(X2(1),X1(1))
  XU = MIN1F(X2(N2),X1(N1))
  IF (XU-XL) 2,2,4
  2 WRITE OUTPUT TAPE 6,601,XL,XU
  601 FORMAT (24H0ERROR IN MEET.....XL =E14.6,4HXU =E14.6)
  WRITE OUTPUT TAPE 6 ,600,XP,YP,DY1,DY2,ERROR,
  1 (X(1),D(1), I=1,N)
  GO TO 90
  4 CONTINUE
  N = 21
  ANY = N-1
  DELX = (XU-XL)/ANY
  CALL CURFIT (X1,Y1,A1,N1,0.0,0.2,2)
  CALL CURFIT (X2,Y2,A2,N2,0.0,0.2,2)
  DO 10 I=1,N
  XI = I-1
  X(I) = XL+XI*DELX
  CALL CURVE (A1,X1,Y1,X(I),YY1,ANY,N1,1)
  CALL CURVE (A2,X2,Y2,X(I),YY2,ANY,N2,1)
  D(I) = YY2-YY1
  10 CONTINUE
  IF (D(2)-D(1))20,90,40
  20 DO 30 I=1,N
  30 D(I) = -D(I)
  40 CALL CURFIT (D,X,A,N,0.0,0.2,2)
  CALL CURVE (A,D,X,0.0,XP,ANY,N,1)
  CALL CURVE (A1,X1,Y1,XP,YP1,DY1,N1,3)
  CALL CURVE (A2,X2,Y2,XP,YP2,DY2,N2,3)
  ERROR = YP2-YP1
  YP = (YP2+YP1)*.5
  90 CONTINUE
  600 FORMAT (1H05E20.7//19X1HX17X3HDEL//(2E20.7))
  RETURN
  END
950JX000
950JX
950JX001
950JX002
950JX003
950JX004
950JX005
950JX006
950JX007
950JX008
950JX009
950JX010
950JX011
950JX012
950JX013
950JX014
950JX015
950JX016
950JX017
950JX018
950JX019
950JX020
950JX021
950JX022
950JX023
950JX024
950JX025
950JX026
950JX027
950JX028
950JX029
950JX030
950JX031
950JX032
950JX033
950JX034
950JX035

```

```

SUBROUTINE CONV (P1,P2,DEL,DSTH,M1)
  LABEL
  * 950JHH
  C
  C ROUTINE TO CONTROL CONVERGENCE OF SLIP-STREAM
  C CALCULATION
  C
  C DIMENSION X(20),Y1(20),Y2(20)
  C
  C IF (M1-9) 10,10,20
  C 10 Y1(M1) = P1
  C Y2(M1) = P2
  C X(M1) = DEL
  C DEL = DEL+DSTH
  C GO TO 30
  C
  C 20 CALL MEET (X,Y1,9,X,Y2,9,DEL,P,DUM,DUM)
  C 30 RETURN
  C END

```

950JHH00  
 950JHH  
 950JHH01  
 950JHH02  
 950JHH03  
 950JHH04  
 950JHH05  
 950JHH06  
 950JHH07  
 950JHH08  
 950JHH09  
 950JHH10  
 950JHH11  
 950JHH12  
 950JHH13  
 950JHH14  
 950JHH15  
 950JHH16

```

SUBROUTINE DMOVE (X,Y)
  LABEL
  * 950J11
  C
  C      MOVE DATA FROM Y TO X.      (X=Y)
  C
  C      DIMENSION X(10),Y(10)
  C
  C      DO 10 I=1,10
  C        X(I) = Y(I)
  C      CONTINUE
  C
  C      RETURN
  C      END
950J1100
950J11
950J1101
950J1102
950J1103
950J1104
950J1105
950J1106
950J1107
950J1108
950J1109
950J1110

```

```

SUBROUTINE LOCATE (IT,I,ITT,AC,BC,CC,DC,X)
  LABEL
* 950J0
  DIMENSION AC1(6,20),AC2(6,20)
  20 FORMAT (28H ERROR IN SUBROUTINE LOCATE.)
  C
  X3 = X
  IB = IB
  JB = JB
  IF (IT) 1500,1000,100
  100 IB = 1
  JB = 1
  IF (I) 9,99,99
  9 IF (X3-AC1(1,1))240,10,10
  10 IF (X3-AC1(1,IB)) 140,120,120
  120 IF (AC1(6,IB) - X3) 150,150,130
  C
  130 AC = AC1(2,IB)
  BC = AC1(3,IB)
  CC = AC1(4,IB)
  DC = AC1(5,IB)
  GO TO 401
  C
  140 IB = IB -1
  GO TO 10
  C
  150 IB = IB+1
  IF (IB>NN1) 10,10,240
  99 IF (X3-AC2(1,1)) 240,11,11
  11 IF (X3 - AC2(1,JB)) 180,160,160
  160 IF (AC2(6,JB) - X3) 190,190,170
  C
  170 AC = AC2(2,JB)
  BC = AC2(3,JB)
  CC = AC2(4,JB)
  DC = AC2(5,JB)
  GO TO 401
  C
  180 JB = JB-1
  GO TO 11
  C

```

```

950J0000
950J0
950J0001
950J0002
950J0003
950J0004
950J0005
950J0006
950J0007
950J0008
950J0009
950J0010
950J0011
950J0012
950J0013
950J0014
950J0015
950J0016
950J0017
950J0018
950J0019
950J0020
950J0021
950J0022
950J0023
950J0024
950J0025
950J0026
950J0027
950J0028
950J0029
950J0030
950J0031
950J0032
950J0033
950J0034
950J0035
950J0036
950J0037

```

```

C 190 JB = JB+1
      IF (JB - NN2) 11,11,240
C
C 401 ITT = 1
      GO TO 2000
1000 IF (T) 200,220,220
200 IF (X3 - AC1(1,IB)) 140,210,210
210 IF (AC1(6,IB) - X3) 150,150,380
C
220 IF (X3 - AC2(1,JB)) 180,230,230
230 IF (AC2(6,JB) - X3) 190,380,380
240 WRITE OUTPUT TAPE 6,20
      CALL DUMP
C
1500 REWIND 2
      READ TAPE 2
      READ TAPE 2,AC1,AC2,NN1,NN2
      GO TO 2000
C
380 ITT = 0
2000 RETURN
      END

```

```

950J0038
950J0039
950J0040
950J0041
950J0042
950J0043
950J0044
950J0045
950J0046
950J0047
950J0048
950J0049
950J0050
950J0051
950J0052
950J0053
950J0054
950J0055
950J0056
950J0057
950J0058
950J0059

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```

950JPP00
950JPP
950JPP01
950JPP02
950JPP03
950JPP04
950JPP05
950JPP06
950JPP07
950JPP08
950JPP09
950JPP10

```

```

* SUBROUTINE MOVE1 (IB,BB)
  LABEL
  950JPP
C
  DIMENSION XX3(10),BB(10,100)
  EQUIVALENCE (XX3(7),NPT3)
  IB = 0
  DO 40 I=1,100
    IB = IB+1
  CALL DMOVE (XX3,BB(1,IB))
  IF (NPT3-12345) 40,50,40
  40 CONTINUE
  50 RETURN
  END

```



950JZ039  
 950JZ040  
 950JZ041  
 950JZ042  
 950JZ043  
 950JZ044  
 950JZ045  
 950JZ046  
 950JZ047  
 950JZ048  
 950JZ049  
 950JZ050  
 950JZ051  
 950JZ052  
 950JZ053  
 950JZ054  
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 950JZ070  
 950JZ071  
 950JZ072  
 950JZ073  
 950JZ074  
 950JZ075  
 950JZ076  
 950JZ077  
 950JZ078  
 950JZ079

X2 = XX2(1)  
 Y2 = XX2(2)  
 P2 = XX2(3)  
 TH2 = XX2(4)  
 ZMU2 = XX2(5)  
 R2 = XX2(6)  
 IF (N) 9011,9011,5  
 ZM3A = FSM  
 ZM3B = FSM  
 TH3A = 0.0  
 TH3B = 0.0  
 R3A = 1.0  
 R3B = 1.0  
 FSM2 = FSM\*\*2  
 P3A = (1.0+C10\*FSM2)\*\*(-C3)  
 P3B = P3A  
 ZMU3A = ATANF(SQRTF(1.0/(FSM2-1.0)))  
 X3 = X1+SW\*COSF(W1)  
 Y3 = Y1+SW\*SINF(W1) \*AA  
 Y3B = Y3+SINF(-ZMU3A)\*SFW \*AA  
 Y3A = Y3-SINF(-ZMU3A)\*SFW \*AA  
 X3A = X3-COSF(-ZMU3A)\*SFW  
 X3B = X3+COSF(-ZMU3A)\*SFW  
 ZMU3B = ZMU3A  
 GO TO 783  
 9011 X3A = X3A(1)  
 Y3A = X3A(2)  
 P3A = X3A(3)  
 TH3A = X3A(4)  
 ZMU3A = X3A(5)  
 R3A = X3A(6)  
 X3B = X3B(1)  
 Y3B = X3B(2)  
 P3B = X3B(3)  
 TH3B = X3B(4)  
 ZMU3B = X3B(5)  
 R3B = X3B(6)  
 XA = X3A  
 XB = X3B  
 762 ZM3A = 1.0/SINF(ZMU3A)  
 ZM3B = 1.0 / SINF(ZMU3B)

```

C783 NFLAG = XABSF(N)
      W3 = W1
      SLP1 = (Y3B-Y3A)/(X3B-X3A)
737   T61 = P3B - P3A
      T62 = TH3B - TH3A
      T63 = ZMU3B - ZMU3A
      T64 = R3B - R3A
700   RR2 = 0.5
      P3LS = 1000.
      KTR = 0
      RR1 = .5
      SH1 = T62/2.
      SH2 = (TH1U+TH3A)/2.
      SH3 = 1./SLP1
      SH4 = (Y3A-Y1)/(Y3B-Y3A)
      SH5 = (X3A-X1)/(X3B-X3A)
      SH6 = (AA*(W3+W1) + TH1U + TH3A)/2.
701   DO 771 I=1,20
      SH8 = SH6+RR1*SH1
      SH9 = SINF(SH8)
      SH10 = COSF(SH8)
      SH11 = SH9/SH10
      SH12 = RR1+SH4-(RR1+SH5)*SH3*SH11
      SH13 = 1. - SH3*(SH11+SH1*(RR1+SH5))/(SH10)**2)
      IF (ABSF(SH13) - .00000001) 773,773,772
772   DRR1 = SH12 / SH13
      RR1 = RR1 - DRR1
      IF (ABSF(DRR1) - MAX1F(ABSF(RR1 * .000001) , .00001)) 773,773,771
771   CONTINUE
773   X3 = X3A +RR1*(X3B-X3A)
      Y3 = Y3A +RR1*(Y3B-Y3A)
      P3U = P3A +RR1*T61
      TH3U = TH3A + RR1*T62
      ZMU3U = ZMU3A + RR1*T63
      R3U = R3A +RR1*T64
      T29 = SINF(2.*W3)
      T31 = SINF(W3)**2
      T32 = ZMU3U**2

```

950JZ080  
950JZ081  
950JZ082  
950JZ083  
950JZ084  
950JZ085  
950JZ086  
950JZ087  
950JZ088  
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950JZ111  
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950JZ113  
950JZ114  
950JZ115  
950JZ116  
950JZ117  
950JZ118  
950JZ119  
950JZ120

```

DEL3=ATANF((T32*T29-2.*COSF(X3)/SINF(X3))/(T32*(C1+COSF(2.*X3))+2.
1))
950JZ121
950JZ122
950JZ123
950JZ124
950JZ125
950JZ126
950JZ127
950JZ128
950JZ129
950JZ130
950JZ131
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950JZ152
950JZ153
950JZ154
950JZ155
950JZ156
950JZ157
950JZ158
950JZ159
950JZ160
950JZ161

DEL3=ATANF((T32*T29-2.*COSF(X3)/SINF(X3))/(T32*(C1+COSF(2.*X3))+2.
1))
T28 = SINF(DEL3)**2
TH3 = TH3U +AA*DEL3
ERASB = C4*(T32*T31-C11)
P3= P3U*ERASR
R3= ((T32*T31)/(C5*(T32*T31)-C12)))*C3*ERASB**C2*R3U
T30 = P3/R3
IF (T30) 651,651,703
651 M1 = 2
WRITE OUTPUT TAPE 6,22
GO TO 100
703 T30 = C12*(1.-(T30)**(-C7))-1.
IF (T30-.04) 651,651,705
705 ZMU3 = ATANF(SQRTF(1.0/T30))
778 IF (ABSF(P3-P3LS)-.001*P3) 780,780,715
715 P3LS=P3
IF (KTR-100) 1019,1019,780
1019 KTR = KTR+1
101 GO TO (776,740),NFLAG
776 X2=X3
Y2=Y3
P2=P3
TH2=TH3
ZMU2=ZMU3
R2=R3
NPT2=NPT3
XX2(1) = X2
XX2(2) = Y2
XX2(3) = P2
XX2(4) = TH2
XX2(5) = ZMU2
XX2(6) = R2
10 CALL BODYPT (AA,XX1,XX2,XX3,C1,M1)
X5 = XX3(1)
Y5 = XX3(2)
P5 = XX3(3)
TH5 = XX3(4)
ZMU5 = XX3(5)
R5 = XX3(6)
DO 1122 I=1,6

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```

1122 XX5(I) = XX3(I)
      CONTINUE
      X3=X2
      Y3=Y2
      P3=P2
      TH3=TH2
      ZMU3=ZMU2
      R3=R2
      X2=X5
      Y2=Y5
      P2=P5
      TH2=TH5
      ZMU2=ZMU5
      R2=R5
740   T42 = Y1 -Y3
      T36 = X2 -X1
      T37 = Y2 -Y1
      T39 = (TH2 +AA*ZMU2)/2.
      T40 = (TH1 +AA*ZMU1)/2.
      T38 = P2- P1
      T35 = TH2 -TH1
      T33 = ZMU2 -ZMU1
      T45 = T39 -T40
      T46 = T37/T36
      T43 = X1 -X3
      T47 = T42/T36
      T48 = T43/T36
      T50 = (TH3 +AA*ZMU3)/2.
      T49 = T40 + T50
      IF (TH2+AA*ZMU2-1.0) 3000,3000,3001
3001 DENOM = SQRTF(T36**2-T37**2)
      RR2A = .5
      T501 = TH3+AA*ZMU3
      S2 = SIN(F(T501)/COSF(T501))
      DO 3010 I=1,20
      X4 = X1+(T43-T42/S2)/(T46/S2-1.)
      Y4 = Y1+(X4-X1)*T46
      RR2 = SQRTF((X4-X1)**2+(Y4-Y1)**2)/DENOM
      IF (ABS(F(RR2A-RR2))-MAX1F(.00001*ABS(F(RR2)),.00001)) 711,711,3004
3004 RR2A = RR2
      TH4 = TH1+RR2*T35

```

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950JZ162
950JZ163
950JZ164
950JZ165
950JZ166
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950JZ195
950JZ196
950JZ197
950JZ198
950JZ199
950JZ201
950JZ202
950JZ203

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```

ZMU4 = ZMU1+RR2*T33
T502 = (T501+TH4+AA*ZMU4)/2.
3010 S2 = SIN(T502)/COS(T502)
GO TO 711
3000 RR2 = .5
706 DO 750 I=1,20
T51 = RR2*T45 +T49
T52 = SIN(T51)
T53 = COS(T51)
T54 = T52/T53
FR = T47 +RR2*T46 -(RR2 +T48)*T54
FPR =T46 -T54 -(RR2 +T48)*T45/T53**2
IF (ABS(FPR) - .00000001) 711,711, 751
751 DRR = FR/FPR
RR2= RR2 -DRR
CONTINUE
725 IF (ABS(DRR) - MAX1(.00001 * ABS(DRR) , .00001)) 711, 711, 750
750 CONTINUE
711 IF (ABS(RR2-.5)-.5) 747,747,111
111 IF (NPT2) 60,61,61
60 IF (RR2 + .01) 1160,747,747
1160 WRITE OUTPUT TAPE 6,23
500 M1 = 3
GO TO 100
C
61 IF (RR2) 666,661,661
666 IF (RR2 + .001) 670,747,747
670 WRITE OUTPUT TAPE 6,25,X1,Y1,P1,TH1,ZMU1,W1
WRITE OUTPUT TAPE 6,25,X2,Y2,P2,TH2,ZMU2,W2
WRITE OUTPUT TAPE 6,25,X3,Y3,P3,TH3,ZMU3,W3
WRITE OUTPUT TAPE 6,25,X4,Y4,P4,TH4,ZMU4,W4
WRITE OUTPUT TAPE 6,25,RR2,DRR,DPDW,DTHDW,DW3,T30
WRITE OUTPUT TAPE 6,25,X3A,Y3A,X3B,Y3B,
661 M1 = 5
C
C THE NEXT POINT MUST BE USED AS POINT 2.
C
GO TO 100
C
747 X4 = X1 +RR2*T36
Y4 = Y1 +RR2*T37
950JZ204
950JZ205
950JZ206
950JZ207
950JZ208
950JZ209
950JZ210
950JZ211
950JZ212
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950JZ238
950JZ239
950JZ240
950JZ241
950JZ242
950JZ243
950JZ244

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```

P4 = P1 +RR2*T38
TH4 =TH1 +RR2*T35
ZMU4 =ZMU1+RR2*T33
DPDW = P3U*C4*T32*T29
DTHDW = (C1+1.0)*T28*T31*T32**2/(T32*T31-1.0)**2 - SIN(2.0*DEL3)/950JZ2249
1T29
T13 =(TH4 +TH3)/2.0
T60 =(TH4 +AA*ZMU4)/2.0
T11 =(P4 +P3)/2.0
T12 =(ZMU4 +ZMU3)/2.0
T34 =(Y4 +Y3)/2.0
DW3 = -((P3-P4)/(C1*T11)+A*(TH3-TH4)/((COSF(T12))*(SINF(T12))))
W3=W3+DW3/(DPDW/(C1*T11)+DTHDW/(SINF(T12)/COSF(T12)))
774 GO TO 701
780 M1 = 1
765 IF (RR1) 763,763,1900
1900 IF (RR1-1.0) 100,100,1904
C
763 M1 = 6
GO TO 100
C
NEW 3A AND 3B POINTS UPSTREAM MUST BE USED.
C
1904 M1 = 7
C
NEW 3A AND 3B POINTS DOWNSTREAM MUST BE USED.
C
100 XX3U(1) = X3
XX3(1) = X3
XX3U(2) = Y3
XX3(2) = Y3
XX3U(3) = P3U
XX3U(4) = TH3U
XX3U(5) = ZMU3U
XX3U(6) = R3U
XX3(3) = P3
XX3(4) = TH3
XX3(5) = ZMU3
XX3(6) = R3
XX3(8) = SIGNF(W3,XX1(8))
RETURN
950JZ2245
950JZ2246
950JZ2247
950JZ2248
950JZ2249
950JZ2250
950JZ2251
950JZ2252
950JZ2253
950JZ2254
950JZ2255
950JZ2256
950JZ2257
950JZ2258
950JZ2259
950JZ2260
950JZ2261
950JZ2262
950JZ2263
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950JZ2285

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